october 1958
the
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engineers

# Proceedings of the IRE

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WESTREX STEREODISK SYSTEM
ELF ELECTROLUMINESCENT DISPLAY
HELITRON OSCILLATOR
SUBMILLIMETRIC GUIDED WAVES
SOLAR INFLUENCE ON VHF SCATTER
ELECTRODES REQUIRED FOR DESIRED FIELD
VOLTAGE SENSITIVE SWITCH
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HARMONIC GENERATION
ERROR-CORRECTING ENCODER
COMPUTER FOR SPATIAL PROBLEMS
LEAKAGE FLUX AROUND FOCUSING MAGNETS
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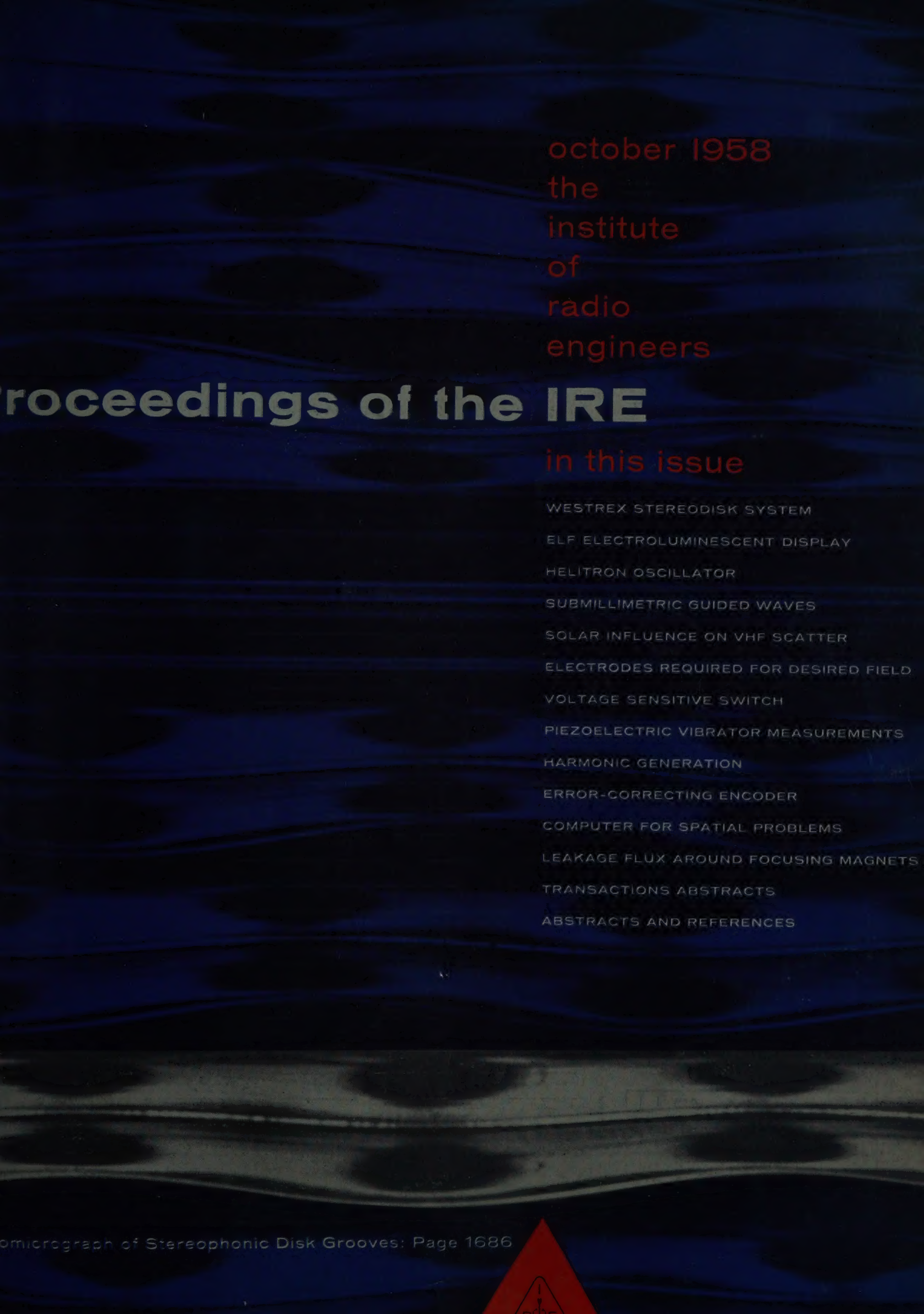


omicrograph of Stereophonic Disk Grooves: Page 1686

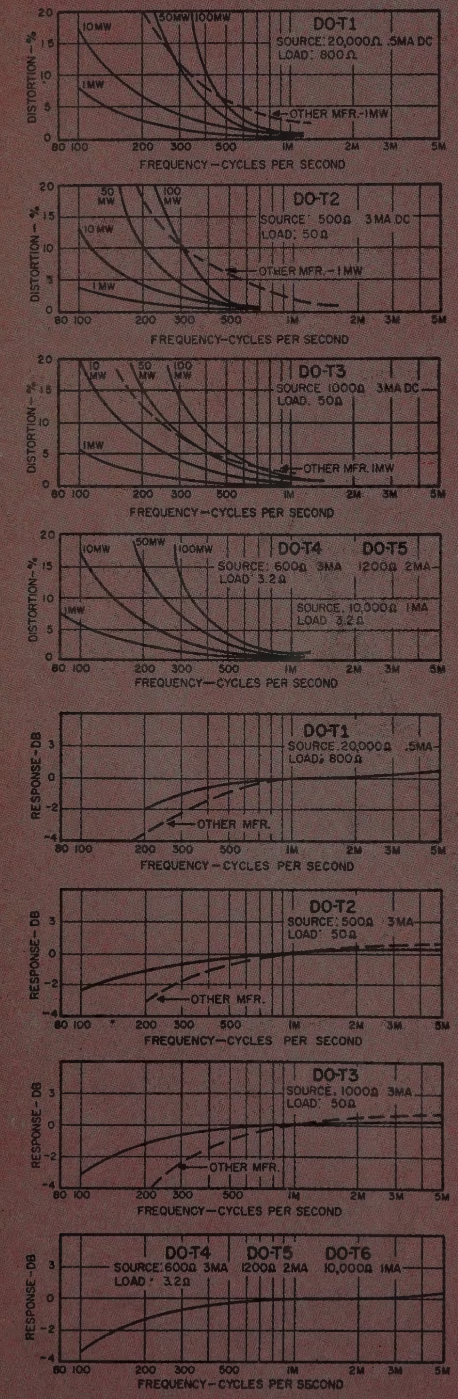
# TO MAKE YOUR EQUIPMENT SMALLER TH
# MORE RELIAB

## REVOLUTIONARY TRANSISTOR* TRANSFORMERS, HERMETIC TO MIL-T-

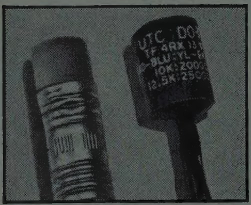
Conventional miniaturized transistor transformers have inherently poor electrical character-
istics, perform with insufficient reliability and are woefully inadequate for many applications
The radical design of the new UTC DO-T and DI-T transistor transformers provides unprece-
dented power handling capacity and reliability, coupled with extremely small size.

### TYPICAL DO-T PERFORMANCE CURVES

Power curves based on setting output power at 1 KC, then maintaining same input level over frequency range.



# DO-T



⁵⁄₁₆ Dia. x ¹³⁄₃₂, ¹⁄₁₀ Oz.

**High Power Rating** . . . up to 100 times greater.

**Excellent Response** . . . twice as good.

**Low Distortion** . . . reduced 80%.

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**Moisture Proof** . . . hermetic to MIL-T-27A.

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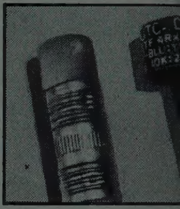
**Anchored Leads** . . . will stand 10 lb. pull, plastic leads for printed circuits.

# DI-



⁵⁄₁₆ Dia. x ¼, ½

To fully appreciate DO-T transistor transformers, the curves indicate their performance compared to
similar size units now on the market. DI-T transformers are still smaller in size. Power rating and
characteristics are identical to DO-T, but low frequency response (3 db down point) is 30% higher in fre
Units can be used for different impedances than those shown, keeping in mind that impedance ratio is co
Lower source impedance will improve response and level ratings . . . higher source will reduce them. Uni
be used reversed, input to secondary.

| DO-T No. | MIL Type | Application | Pri. Imp. | D.C. Ma.‡ in Pri. | Sec. Imp. | Pri. Res. | Level Mw. |
|---|---|---|---|---|---|---|---|
| DO-T1 | TF4RX13YY | Interstage | 20,000<br>30,000 | .5<br>.5 | 800<br>1200 | 850 | 50 |
| DO-T2 | TF4RX17YY | Output | 500<br>600 | 3<br>3 | 50<br>60 | 60 | 100 |
| DO-T3 | TF4RX13YY | Output | 1000<br>1200 | 3<br>3 | 50<br>60 | 115 | 100 |
| DO-T4 | TF4RX17YY | Output | 600 | 3 | 3.2 | 60 | 100 |
| DO-T5 | TF4RX13YY | Output | 1200 | 2 | 3.2 | 115 | 100 |
| DO-T6 | TF4RX13YY | Output | 10,000 | 1 | 3.2 | 1000 | 100 |
| DO-T7 | TF4RX16YY | Input | 200,000 | 0 | 1000 | 8500 | 25 |
| DO-T8 | TF4RX20YY | Reactor 3.5 Hys. @ 2 Ma. DC, 1 Hy @ 5 Ma. DC (DI-T8 is 2.5 Hy @ 2 Ma.) | | | | 630 | |
| DO-T9 | TF4RX13YY | Output or driver | 10,000<br>12,500 | 1<br>1 | 500 CT<br>600 CT | 800 | 100 |
| DO-T10 | TF4RX13YY | Driver | 10,000<br>12,500 | 1<br>1 | 1200 CT<br>1500 CT | 800 | 100 |
| DO-T11 | TF4RX13YY | Driver | 10,000<br>12,000 | 1<br>1 | 2000 CT<br>2500 CT | 800 | 100 |
| DO-T12 | TF4RX17YY | Single or PP output | 150 CT<br>200 CT | 10<br>10 | 12<br>16 | 11 | 500 |
| DO-T13 | TF4RX17YY | Single or PP output | 300 CT<br>400 CT | 7<br>7 | 12<br>16 | 20 | 500 |
| DO-T14 | TF4RX17YY | Single or PP output | 600 CT<br>800 CT | 5<br>5 | 12<br>16 | 43 | 500 |
| DO-T15 | TF4RX17YY | Single or PP output | 800 CT<br>1070 CT | 4<br>4 | 12<br>16 | 51 | 500 |
| DO-T16 | TF4RX13YY | Single or PP output | 1000 CT<br>1330 CT | 3.5<br>3.5 | 12<br>16 | 71 | 500 |
| DO-T17 | TF4RX13YY | Single or PP output | 1500 CT<br>2000 CT | 3<br>3 | 12<br>16 | 108 | 500 |
| DO-T18 | TF4RX13YY | Single or PP output | 7500 CT<br>10,000 CT | 1<br>1 | 12<br>16 | 505 | 500 |
| DO-T19 | TF4RX17YY | Output to line | 300 CT | 7 | 600 | 19 | 500 |
| DO-T20 | TF4RX17YY | Output or matching to line | 500 CT | 5.5 | 600 | 31 | 500 |
| DO-T21 | TF4RX17YY | Output to line | 900 CT | 4 | 600 | 53 | 500 |
| DO-T22 | TF4RX13YY | Output to line | 1500 CT | 3 | 600 | 86 | 500 |
| DO-T23 | TF4RX13YY | Interstage | 20,000 CT<br>30,000 CT | .5<br>.5 | 800 CT<br>1200 CT | 850 | 100 |
| DO-T24 | TF4RX16YY | Input (usable for chopper service) | 200,000 CT | 0 | 1000 CT | 8500 | 25 |
| DO-T25 | TF4RX13YY | Interstage | 10,000 CT<br>12,000 CT | 1<br>1 | 1500 CT<br>1800 CT | 800 | 100 |
| DO-T26 | TF4RX20YY | Reactor 6 Hy. @ 2 Ma. DC, 1.5 Hy. @ 5 Ma. DC | | | | 2100 | |
| DO-T27 | TF4RX20YY | Reactor 1.25 Hy. @ 2 Ma. DC, .5 Hy. @ 11 Ma. DC | | | | 100 | |
| DO-TSH | Drawn Hipermalloy shield and cover for DO-T's, provides 25 to 30 db shielding. | | | | | | |

‡DCMA shown is for single ended useage (under 5% distortion—100MW—1KC) . . . for push pull, DCMA ca
any balanced value taken by .5W transistors (under 5% distortion—500MW—1KC)

-T units have been designed for transistor application
y . . . not for vacuum tube service. Patents Pending

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VOLUME 46, NUMBER 10

**October, 1958**

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**COVER** When the grooves of a 45-45 stereophonic disk are magnified 100 times, the recorded signal becomes discernible as variations in both the shading (depth) and the width of the grooves. If only one channel is recorded, only one side of each groove varies in width, while the other side remains essentially straight, as shown in this photograph from the article on page 1686.

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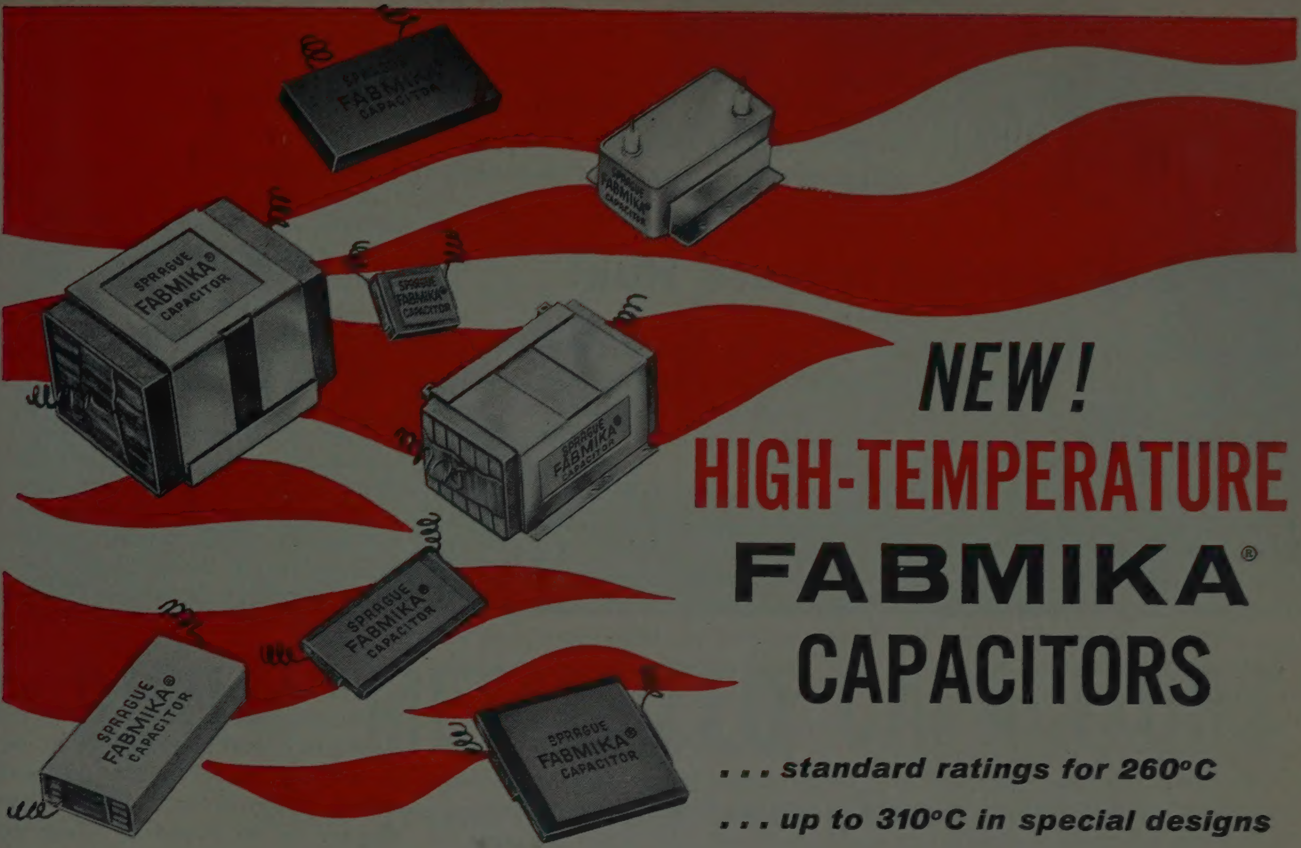

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**The pursuits of our engineers often lead to strange and interesting sidelines. Recently Fred Pogust and Adam Gaus of our Aviation Systems Research Department found themselves with a task which took on all the aspects of a treasure hunt.**

# Engineer's Treasure Hunt

In evaluating a radio navigation system, we had to take repetitive readings at a dozen or so points to determine the day-to-day and month-to-month accuracy of the radio readings. In this system, an uncommonly accurate one, the points of constant phase difference between transmitters lie on hyperbolas that are fixed for a given frequency and location of transmitter stations. Knowing the latitude and longitude of the transmitting stations, if we knew our own latitude and longitude, it would be a simple matter for a mathematician (who easily calculates spherical to hyperbolic conversions) to tell us what phase difference to expect.

Determining the latitude and longitude of our observation points, it seemed, would be a relatively easy job. We went right to the series of quadrangle maps published in profusion by the U. S. Geological Survey and the U. S. Corps of Engineers. These are greatly detailed maps from which latitude and longitude can be read to an accuracy of perhaps 50 feet. But alas! we were looking for accuracies in the order of 10 feet.

Then we learned of the existence of triangulation stations, those points on the face of the earth to which our national map makers accredit accuracies of one thousandth of a second of latitude and longitude (roughly one inch). This was more than we had bargained for, but we could find no middle ground. Therefore we decided to use triangulation stations* for our observation points. We began our hunt (treasure hunt, if you will) for triangulation stations—and opened the door on a storehouse of Americana and a library of evidence of the ravages of time, tide and man on the crust of this earth.

There are a few men who make a hobby of "recovering" triangulation stations. Some of these stations date back to the early nineteenth century and have been recovered and re-recovered down through the years. They all bear names; a few samples from our own Long Island area are Oscar, Plan, Staff, Sky, Green and Success Rock Spindle. Each were christened, we gather, by the engineer who planted the little brass plate in the length of terra-cotta pipe in a bed of concrete 2 or 3 feet below the surface of the earth.

The clues for triangulation station treasure hunting were provided to us by the New York Office of the U. S. Coast and Geodetic Survey. They consisted of hundreds of finely printed pages, setting forth the history of each station as well as the best way of finding it. Here is an example of such a clue:

> GOVERNOR (Nassau County, N.Y., P.C.W., 1914)—In order to see either N or S, Mr. Whitney was forced out on concrete sea wall, where the standard disk station mark was cemented in a drill hole in the wall. This wall, which extends along the W shore of Oyster Bay, is broken at this point by a semi-circular projection of about 15 meters diameter, which is directly in front of Gared Beckman's gateway.
>
> Station is located about 1 meter S from where the semicircular project meets the straightaway, and ¾ of a meter E of telephone pole No. 21. Reference mark was made as follows: A hole about 2 feet deep was dug in the ground. A suitable stake about 4 feet in length was then driven firmly into the ground; a piece of tile pipe about 2 feet long was slipped over the stake and filled with concrete. A batch of concrete was placed at the base of the tile and the remainder of the hole was filled with earth. A standard reference mark was then placed in the top of the tile, with the arrow pointing toward the station. Reference mark rises from 4 to 6 inches above the surrounding surface, with a batch of concrete placed around it.

A later report corrected Gared Beckman's name to Mr. Gerard Beekman. Then in 1939, F.R.G. reported the station recovered and noted: "The reference mark . . . was dug for but not found. It is believed to have been removed or deeply covered. Flower beds make more extensive digging at this point impractical."

We didn't have as much luck as F.R.G. did in 1939. Somebody bulwarked the sea wall and cemented over Mr. Whitney's standard disk. We found telephone pole No. 21 and the semicircular projection and we were sure we were within 10 feet of the quarry. That was par for the game we were playing.

After hunting for stations covered by drifting sand, pavement and poison ivy—and discovering that most of them have been washed away, eroded away, torn down or torn up—we are glad to report that we deciphered the clues and followed the trail that led to enough of these little-known landmarks to allow us to continue on our electronic way.

A complete bound set of our second series of articles is available on request. Write to Harold Hechtman at AIL for your set.

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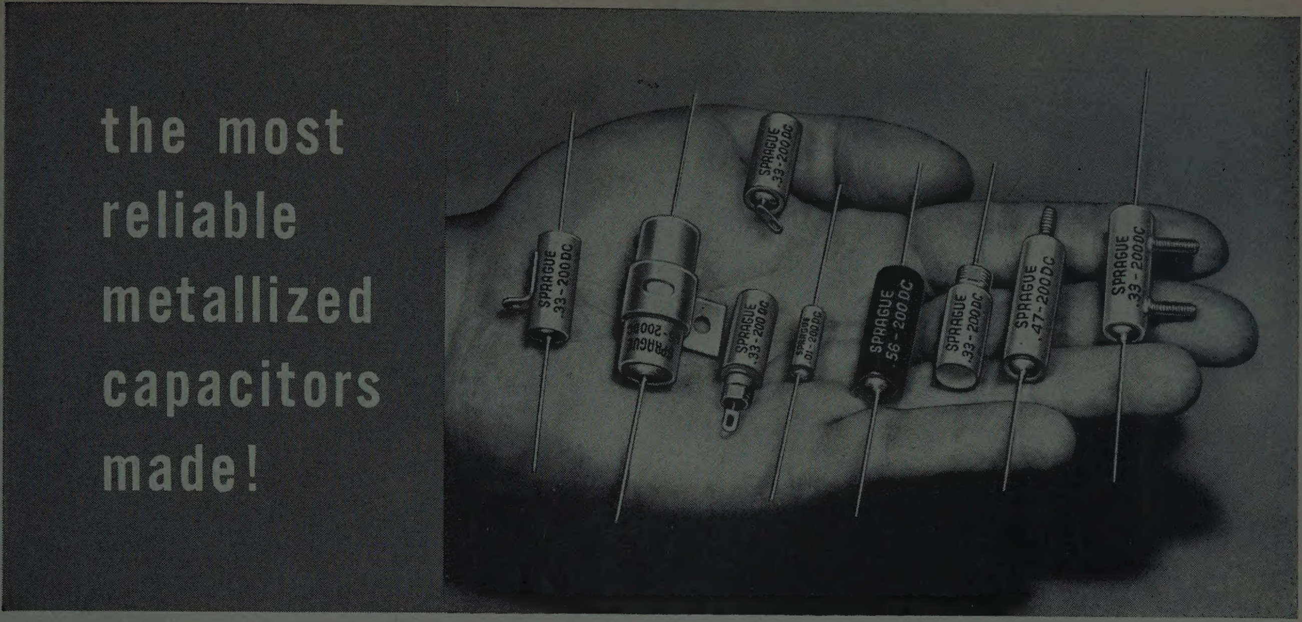
* Not to be confused with bench marks which are controlled only in the vertical. Civil engineers are more concerned with absolute elevation and usually settle for relative horizontal control.



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Tung-Sol-developed miniature damper

## tubes cut costs of TV manufacture!

*New 6AF3 and 12AF3 permit TV set-makers to profit more fully from economies of automated production.*

Two new Tung-Sol damper diodes—6AF3 and 12AF3—bring TV manufacturers substantial dollar-savings through increased efficiency. Modern automatic assembly equipment is better able to process the miniature, button-stem dampers than prior octal-base types. Also, the new types allow standardization of tube and socket size—a big plus in printed circuit usage.

In addition to these cost-cutters, 6AF3 and 12AF3 offer premium performance. They approach the high ratings of the 6AU4GTA and 19AU4GTA . . . have the same heater power as the 6AX4GT and 12AX4GTA. Set-testing under actual overload conditions indicates the new tubes carry a greater "safety factor" than any previous damper.

The economy and top-flight quality of the 6AF3 and 12AF3 characterize the entire Tung-Sol tube line. For complete data on the new miniature dampers . . . to fill any entertainment socket, contact: *Tung-Sol Electric Inc., Newark 4, New Jersey.*

New Tung-Sol miniature dampers compared with types they replace

| | BASING | LOAD-RATING | HEATER-RATING |
|---|---|---|---|
| 6AF3<br>12AF3 | Miniature | 185ma* | 6.3v, 1.2a<br>12.6v, 0.6a |
| 6AX4GT<br>12AX4GTA | Octal | 125ma† | 6.3v, 1.2a<br>12.6v, 0.6a |
| 6AU4GTA<br>19AU4GTA | Octal | 190ma† | 6.3v, 1.8a<br>18.9v, 0.6a |
| 12D4 | Octal | 145ma† | 12.6v, 0.6a |

*According to Design Maximum System of Ratings
†According to Design Center System of Ratings

**TUNG-SOL®**

HYPAC
ERA
ERA PACIFIC, INC.
SANTA MONICA
CALIFORNIA
NEED
HIGH
VOLTAGE?

**HYPAC® MINIATURE HI-VOLTAGE DC POWER SUPPLIES**

**FEATURES:**

- *Static, Semiconductor Designs*
- *High Voltage DC Output, AC or DC Inputs*
- *Small Size, Light Weight*
- *High Efficiency, Low Heat Dissipation*
- *Low Ripple Content*
- *Available In Mil. Spec. or Commercial Types*
- *Fast Transient Response*
- *Instant Warm-Up Time*
- *Regulation for both Line and Load*
- *Rugged, Long Life Designs*
- *For All High Voltage Applications*

A new concept in miniaturized high voltage D.C. power supplies, these self-contained units provide high voltage regulated outputs by using solid state devices and magnetic components in advanced circuitry. Conversion and control functions are accomplished at low voltage levels and hence safe and reliable operation of all semi-conductors result. All units are transient protected and short-circuit proof.

**APPLICATIONS:**

- Cathode Ray Indicators
- Klystron, Traveling-Wave Tubes
- Microwave Equipment Powering
- Geiger, Scintillation Counters
- Dielectric Testing
- All High Voltage Applications

**TYPICAL STANDARD MODELS**

High Voltage DC Output, AC Input (400 cps)

| Model No. | Output (DC) | Regulation | Vol. (approx.) | Price* |
|---|---|---|---|---|
| HAR1K/2F | 1000v @ 2ma | ± 0.5% | 65 cu. in. | $195.00 |
| HAR3K/2F | 3000v @ 2ma | ± 0.5% | 90 cu. in. | 215.00 |

High Voltage DC Output, AC Input (60 cps)

| Model No. | Output (DC) | Regulation | Vol. (approx.) | Price* |
|---|---|---|---|---|
| HAR1KA/5(L) | 500-1000v @ 5ma | ± 0.5% | 175 cu. in. | $220.00 |
| HAR3KA/5(L) | 1500-3000v @ 5ma | ± 0.5% | 175 cu. in. | 235.00 |

High Voltage DC Output, DC Input

| Model No. | Output (DC) | Regulation | Vol. (approx.) | Price* |
|---|---|---|---|---|
| HDR1K/2 | 1000v @ 2ma | ± 0.5% | 35 cu. in. | $160.00 |
| HDR3K/2 | 3000v @ 2ma | ± 0.5% | 65 cu. in. | 185.00 |

Write For Quotations On Special Designs

*F.O.B. Santa Monica, California. Prices subject to change without notice
Write For Complete Technical Bulletin — Catalogue #501

**ERA PACIFIC, INC.**
Subsidiary of Electronic Research Associates
1760 Stanford Street • Santa Monica, California • Exbrook 3-0511

## Meetings with Exhibits

**As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.**

Δ

*October 8-10, 1958*
**IRE Canadian Convention,** Exhibition Park, Toronto, Canada.
*Exhibits:* Mr. F. G. Heath, Canadian Convention, 1819 Yonge St., Toronto, Canada.

*October 13-15, 1958*
**National Electronics Conference,** Hotel Sherman, Chicago, Ill.
*Exhibits:* Mr. Brendon C. Hawkins, National Electronics Conference, Inc., 184 E. Randolph St., Chicago 1, Ill.

*October 20-22, 1958*
**Fourth Annual Symposium on Aeronautical Communications,** Hotel Utica, Utica, N.Y.
*Exhibits:* Mr. Robert E. Gaffney, 50 Cambridge Rd., Whitesboro, N.Y.

*October 27-29, 1958*
**East Coast Aeronautical and Navigational Electronics Conference,** Lord Baltimore Hotel & 7th Regiment Armory, Baltimore, Md.
*Exhibits:* Mr. R. L. Pigeon, Westinghouse Electric Corp., Air Arm Div., P.O. Box 746, Baltimore, Md.

*November 17-20, 1958*
**Conference on Magnetism & Magnetic Materials,** Sheraton Hotel, Philadelphia, Pa.
*Exhibits:* Mr. D. O. Schwennesen, Magnetic Metals Co., Camden, N.J.

*November 19-20, 1958*
**Northeast Electronics Research and Engineering Meeting** (NEREM), Mechanics Building, Boston, Mass.
*Exhibits:* Mr. Stuart K. Gibson, Instruments of New England, 108 Greenwood Lane, Waltham 54, Mass.

*December 3-5, 1958*
**Eastern Joint Computer Conference** Bellevue Stratford Hotel, Philadelphia, Pa.
*Exhibits:* Mr. John M. Broomall, Burroughs Corp., Paoli, Pa.

*December 3-5, 1958*
**Second National Symposium on Global Communications,** Colonial Inn Desert Ranch, St. Petersburg Beach, Fla.
*Exhibits:* Mr. Robert L. Lazarchik, Sperry-Rand Corp., P.O., Box 1828, Clearwater, Fla.

*December 4-5, 1958*
**PGVC Annual Meeting,** Hotel Sherman, Chicago, Ill.
*Exhibits:* Mr. Frederick L. Hilton, 4501 Augusta Blvd., Chicago, Ill.

*December 9-11, 1958*
**Mid-America Electronics Convention,** Municipal Auditorium, Kansas City, Mo.
*Exhibits:* Mr. Leo Schlesselman, Bendix Aviation Corp., Box 1159, Kansas City 41, Mo.

(Continued on page 10A)

*to meet today's need for instantaneous spectrum analysis*

KAY ELECTRIC CO.
PINE BROOK, N.J.

Catalog No. 695

*NEW*

**KAY**

## *Sonalyzer*

MODEL 30

FOR

- **Immediate Display of Complex Waveforms up to 20 kc**
- **Dynamic Translation of Transient Responses**
- **Display of Fourier Frequency Components . . . Doppler Effects**

# 30-CHANNEL
# ALL-ELECTRONIC SPECTRUM ANALYZER

This instrument and the *Sonalyzer Model 100* fulfill the current need for rapid, accurate spectrum analysis for such pressing applications as the study of satellite signals, telemetering, transmission jamming, tube microphonics, the transmission of coded frequencies, and Doppler Radar. In addition, both *Sonalyzers* will perform many of the same functions that earlier vibration analyzers were used for, including: acoustic studies, shock and vibration analysis for equipment inspection, phonetic studies, speech education of the deaf, etc. Both instruments will display the Fourier frequency components of sonic and ultrasonic disturbances of short duration.

The Kay *Sonalyzer Model 30* relates a single amplitude to frequency, making an instantaneous graphic display of complex audio waveforms. It is a heterodyne-type analyzer which separates 4-kc-wide bandwidths up to 20 kc (higher on special order) into 29 equal frequency bands. A 30th channel is provided for reference.

The energy in each band is the ordinate while frequency is the abscissa of the scan. The signal to be analyzed is amplified and modulated by a high frequency local oscillator. The modulated signal is amplified and applied to 29 crystal filters, each with a 135-cps bandwidth.

An electronic commutating circuit scans the outputs of these filters in rapid sequence and applies the energy to the indicating electrode. The scan of the indicator is synchronized in a 1 :1 ratio with the electronic commutator.

## SPECIFICATIONS

**Frequency Range:** Standard unit 100-4000 cps; other ranges in 4-kc bands to 20,000 cps and higher on request.

FILTER CHANNELS
- **Number:** 29 active, 1 reference.
- **Bandwidth:** 135 cps each (special filter bandwidths upon request).
- **Center Frequencies:** 135 cps intervals throughout frequency range from 135 to 3915 cps per band.

AUDIO AMPLIFIER CHARACTERISTICS
- **Frequency Response:** Flat, or with high frequency emphasis.
- **Gain:** 60 db, with automatic gain control.

**Dimensions:** 18½" x 10½" x 20½".
**Weight:** 36 lbs.
**Price:** **$1995.00,** f.o.b. factory.

FOR ANALYSIS TO 50 KC

**KAY**

## *Sonalyzer*

MODEL 100
Catalog No. 696-A

## 100-CHANNEL MAGNETOSTRICTION FILTER ANALYZER

The *Sonalyzer Model 100* analyzes 2500 cps bandwidths in the 50-7,500 cps range in three bands. With an external oscillator, it will cover up to 50 kc in the same 2500 cps bandwidths. The spectrum under analysis is simultaneously applied to 100 25-cps-spaced magnetostriction filters, each 32 cps wide. The energy at the output of each filter is sampled in sequence by a high-speed capacitance commutator. Out-of-phase summation of these scanned filter outputs achieves noise cancellation and frequency resolution high enough to distinguish signals 60 cycles apart.

The *Sonalyzer Model 100* is sensitive enough to detect an input as low as 0.5 mv; its linearity is such that the voltage-in to voltage-out ratio is linear to within ±1.5 db.

**Price:** **$4975.00,** f.o.b. factory.

*Write for 1958 Kay Catalog*

**KAY ELECTRIC COMPANY**

Dept. I-10 Maple Avenue, Pine Brook, N.J. CApital 6-4000

**Ballantine** SENSITIVE ELECTRONIC VOLTMETER

Battery Operated

A.C. VOLTS
DECIBELS
BALLANTINE LABORATORIES INC
VOLTS FULL SCALE

**VOLTAGE RANGE:**
100 microvolts to 1000 volts rms of a sine wave in 7 decade ranges.

**INPUT IMPEDANCE:**
2 megohms shunted by 10 mmfd on high ranges and 25 mmfd on low ranges.

**FREQUENCY RANGE:**
2 cps to 150,000 cps.

**ACCURACY:**
3% except 5% below 5 cps and above 100,000 cps and [illegible] *for any point on meter scale.*

MODEL 302C—Price $245.

- Available accessories increase the voltage range from 20 microvolts to 10,000 volts.
- Available precision shunt resistors permit the measurement of AC currents from 10 amperes down to one-tenth of a microampere.
- Features the well-known Ballantine logarithmic voltage and uniform DB scales.
- Battery life over 100 hours.
- Can also be used as a flat pre-amplifier with a maximum gain of 60 DB. Because of the complete absence of AC hum, the amplifier section will be found extremely useful for improving the sensitivity of oscilloscopes.

*For further information on this and other Ballantine instruments write for our new catalog.*

BALLANTINE LABORATORIES, INC.
102 Fanny Road, Boonton, New Jersey

## Meetings with Exhibits

(*Continued from page 8A*)

*March 2-6, 1959*

**Western Joint Computer Conference,** Fairmont Hotel, San Francisco, Calif.

*Exhibits:* Mr. H. K. Farrar, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco 5, Calif.

*March 23-26, 1959*

**Radio Engineering Show and National IRE Convention,** New York Coliseum and Waldorf-Astoria Hotel, New York, N.Y.

*Exhibits:* Mr. William C. Copp, Institute of Radio Engineers, 72 West 45th St., New York 36, N.Y.

*April 5-10, 1959*

**Fifth Nuclear Congress,** Cleveland, Ohio.

*Exhibits:* Dr. John C. Simons, Jr., National Research Corp., 70 Memorial Drive, Cambridge 42, Mass.

*April 16-18, 1959*

**SWIRECO, Southwestern IRE Regional Conference & Electronics Show,** Dallas Memorial Auditorium & Baker Hotel, Dallas, Tex.

*Exhibits:* Mr. John McNeely, Southwestern Bell Telephone Co., 308 South Akard St., Dallas 1, Tex.

*May 4-6, 1959*

**National Aeronautical and Navigational Electronics Conference,** Dayton Biltmore Hotel, Dayton, Ohio.

*Exhibits:* Mr. John Kinnally, 203 Talbott Bldg., Dayton 2, Ohio.

*May 6-8, 1959*

**Seventh Regional Conference and Trade Show,** University of New Mexico, Albuquerque, N.M.

*Exhibits:* Mr. H. S. Wescott, Jr., Hoover Electronics Co., 1122 C. San Mateo, S.E., Albuquerque, N.M.

*June 4-5, 1959*

**Third National Conference on Productions Techniques,** Villa Hotel, San Mateo, Calif.

*Exhibits:* Mr. Estrada Fanjul, Stanford Research Institute, Menlo Park, Calif.

*June 13-22, 1959*

**International Conference on Information Processing,** Palais d'Exhibition, Paris, France.

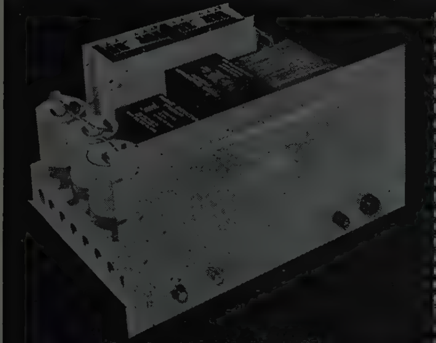
*Exhibits:* Mr. E. M. Grabbe, Ramo Wooldridge Corp., Box 45067, Airport Station, Los Angeles 45, Calif.

∆

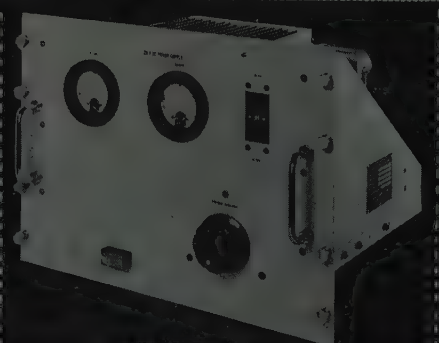
Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

# STANDARD **MISSILE** GROUND CHECKOUT AND LAUNCHING
# "DC POWER SUPPLIES"
BY
# PERKIN

**PROVEN** in production use in the Nation's Major Missile Programs


24-32 VOLTS @ 10 AMPS
MODEL NO. M990

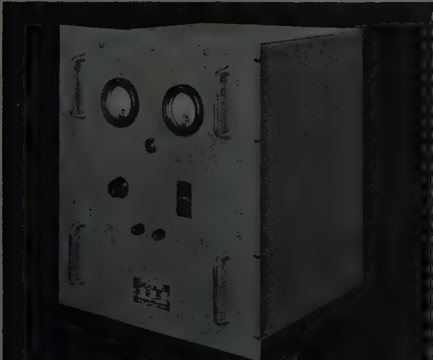
Transistor—Mag amp power supply
DC Output: 24-32V @ 10 amps
AC Input: 105-125V, 1 phase, 60 cps.
Static Regulation: ±0.1% line & load
Dynamic Regulation: ±0.1% line; ±1% load
Ripple: 1 MV R.M.S. maximum
Output Impedance: 0.05 ohms, 0-20 KC
Protection: Short circuit proof; unit has automatic current limiting at 125% of rated load
Dimensions: 19"W x 10½"H x 15"D rack panel mount
Meets Spec. MIL-T-4860


0-32 VOLTS @ 25 AMPS
MODEL NO. M1071

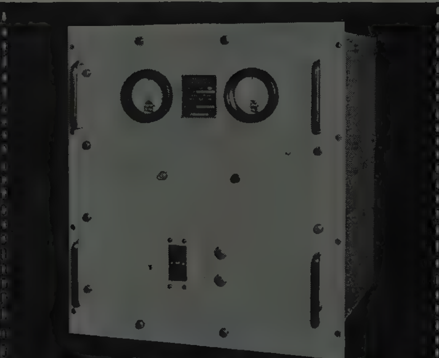
Mag-amp power supply
D.C. Output: 0-32V @ 25 amps
(Surge loads to 35A for 30 min. or less)
A.C. Input: 115V, 1 phase, 60 cps.
Regulation: ±1% 28 volts—
Not stabilized for A.C. line voltage changes.
Ripple: 1% RMS @ 32V and full load
Response Time: 0.1 to 0.2 seconds
Dimensions: 19"W x 14' H x 15"D
Rack panel mount
Meets Spec. MIL-E-4158A

24-32 VOLTS @ 30 AMPS
MODEL NO. MTR28-30-2

Transistor—Mag amp power supply.
D.C. Output: 24-32V @ 30 amps
A.C. Input: 105-125V, 1 phase, 60 cps
Static Regulation: ±0.1% line and load
Dynamic Regulation: ±0.1% line
±1% for full load changes
Ripple: 7 MV RMS max.
Output Impedance: 0.05 ohms 0 to 20 KC
Protection: Short circuit proof; unit has automatic current limiting at 125% rated load
Dimensions: 19"W x 21¼"H x 14"D
Rack panel mount
Meets Spec. MIL-E-4970


24-32 VOLTS @ 100A
MODEL M989

Mag-amp power supply
D.C. Output: 24-32V @ 100 amps
A.C. Input: 208/230 or 460V ±10%
3 phase, 60 cps
Regulation: ±½% for line & load
Ripple: 1% RMS
Response Time: 100 milliseconds
Dimensions: 19"W x 21"H x 16"D
Rack panel mount
Unit incorporates remote sensing.
Meets Spec. MIL-E-4970


24-32 VOLTS @ 100A
MODEL M1136A

Transistor—Mag amp power supply.
D.C. Output: 24-32V @ 100 amps
A.C. Input: 208V ±10%, 3 phase, 60 cps.
Static Regulation: ±0.1% line, ±0.2% for load
Dynamic Regulation: ±0.5% line,
±2V. for full load changes
Ripple: 10 MV RMS max.
Dimensions: 19"W x 21"H x 18"D
Rack panel mount
Meets Spec. MIL-E-4970

24-32 VOLTS @ 500 Amps
MODEL NO. M1134B

Transistor—Mag amp power supply
D.C. Output: 24-32V @ 500 amps
A.C. Input: 208/230/460 V ±10%
3 phase, 60 cps
Static Regulation: 0.1% line; 0.1% load
Dynamic Load Regulation: ±15% for full load changes
Ripple: ½% RMS max.
Response Time: Adjustable 20-200 MS
Dimensions: 26"W x 68"H x 32"D
Meets Spec. MIL-P-6457A

*For further data, contact Perkin Factory or Sales Offices.*

| | |
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| **Denver,**<br>ALpine 5-1196 | **Atlanta,**<br>CEdar 7-7801 |
| **Detroit,**<br>HO 8-2461 | **Orlando,**<br>CH 1-2128 |
| **San Francisco,**<br>EMerson 9-3354 | **Syracuse,**<br>Glbson 6-0220 |

# PERKIN
## PERKIN ENGINEERING CORPORATION
345 KANSAS STREET, EL SEGUNDO CALIFORNIA • OREGON 87215

**New York area office:** Sales & Warehousing: 25 Great Neck Road, Great Neck, L. I., New York, HUnter 2-8606
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**Military Products Division**
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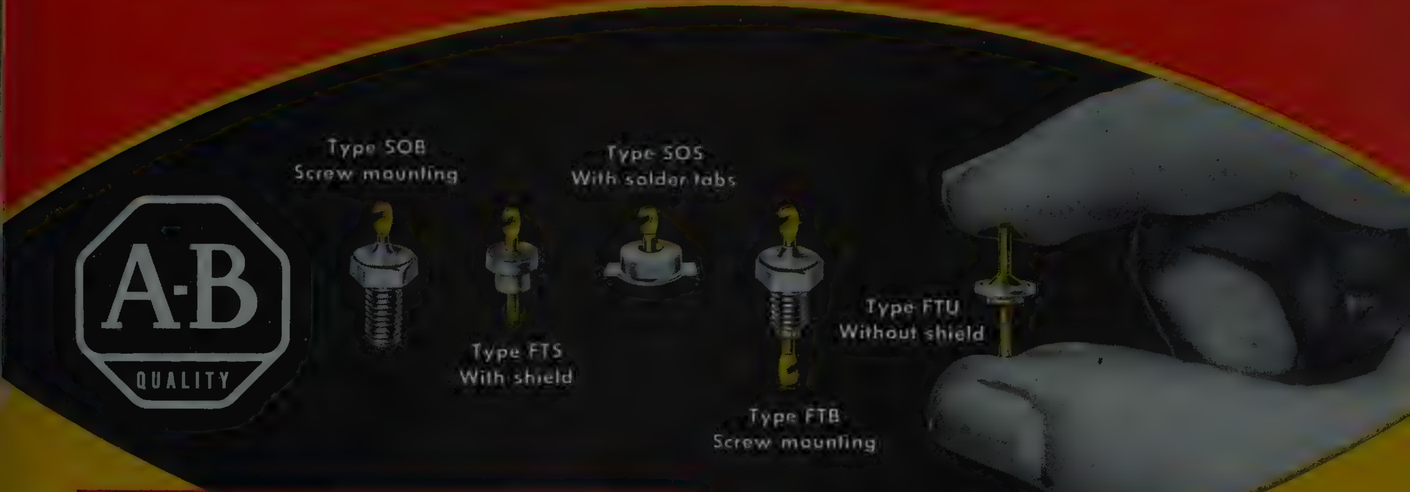
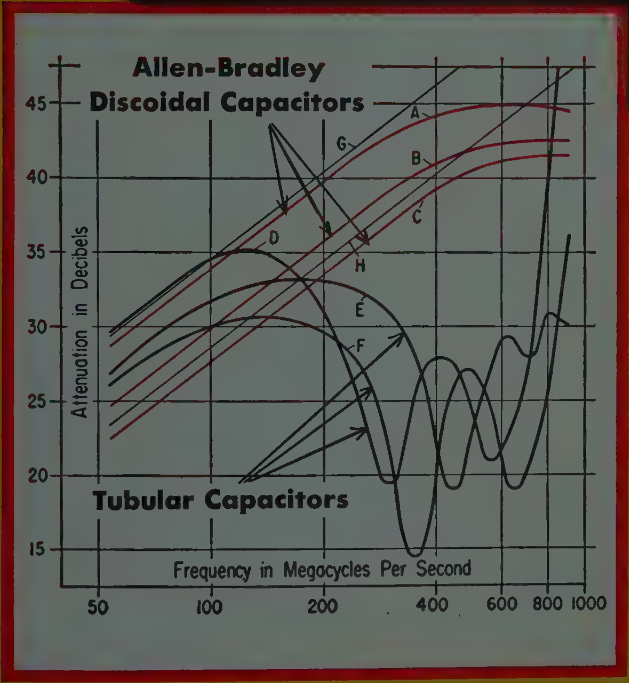
SINGER
MILITARY PRODUCTS DIVISION

# NO PARALLEL RESONANCE

(UP TO 1000 MEGACYCLES)

## WITH ALLEN-BRADLEY DISCOIDAL FEED-THRU AND STAND-OFF CAPACITORS





**Discoidal vs. Tubular Feed-Thru Ceramic Capacitors**

| | |
|---|---|
| Allen-Bradley Discoidal Type.................. | Curve A—1800 MMF at 1 KC Actual<br>Curve B—1150 MMF at 1 KC Actual<br>Curve C— 800 MMF at 1 KC Actual |
| Representative Tubular Type.................. | Curve D—2000 MMF at 1 KC Actual<br>Curve E—1500 MMF at 1 KC Actual<br>Curve F—1400 MMF at 1 KC Actual |
| The "Ideal" Capacitor...................... | Curve G—2000 MMF<br>Curve H—1000 MMF |

## AVOID RADIATION INTERFERENCE FOR VHF AND UHF RECEIVERS

Their unique discoidal design eliminates ALL parallel resonance effects which are normally encountered with tubular type capacitors in the VHF and UHF frequency ranges. With this complete absence of self-resonance, as shown in the graph at left, you can use far greater nominal capacitance values to obtain lower coupling impedances . . . and superior filtering.

The rugged construction of Allen-Bradley discoidal capacitors minimizes breakage during assembly or from thermal shock incurred during soldering. And, these capacitors have *gold plated* terminals to insure faultless soldering every time . . . even after long periods in storage.

Both feed-thru and stand-off capacitors are available in standard nominal capacitance values from 5 mmf to 1,000 mmf.

For suppression of stray radiation at frequencies to 1,000 megacycles, you cannot equal Allen-Bradley discoidal capacitors. Send for Technical Bulletin 5409.

ALLEN-BRADLEY
ELECTRONIC COMPONENTS
QUALITY

5-58-E

Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis. In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

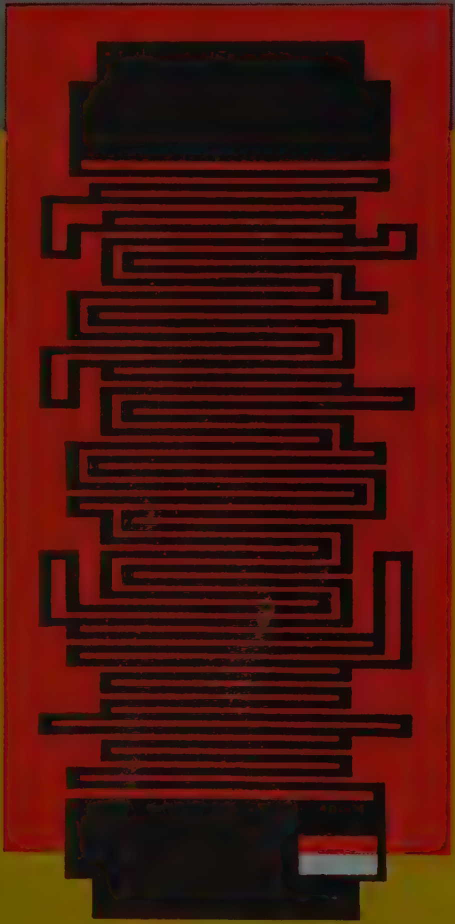
ALLEN-BRADLEY PRESENTS...

# NEW METAL GRID

¼, ½, and 1-WATT

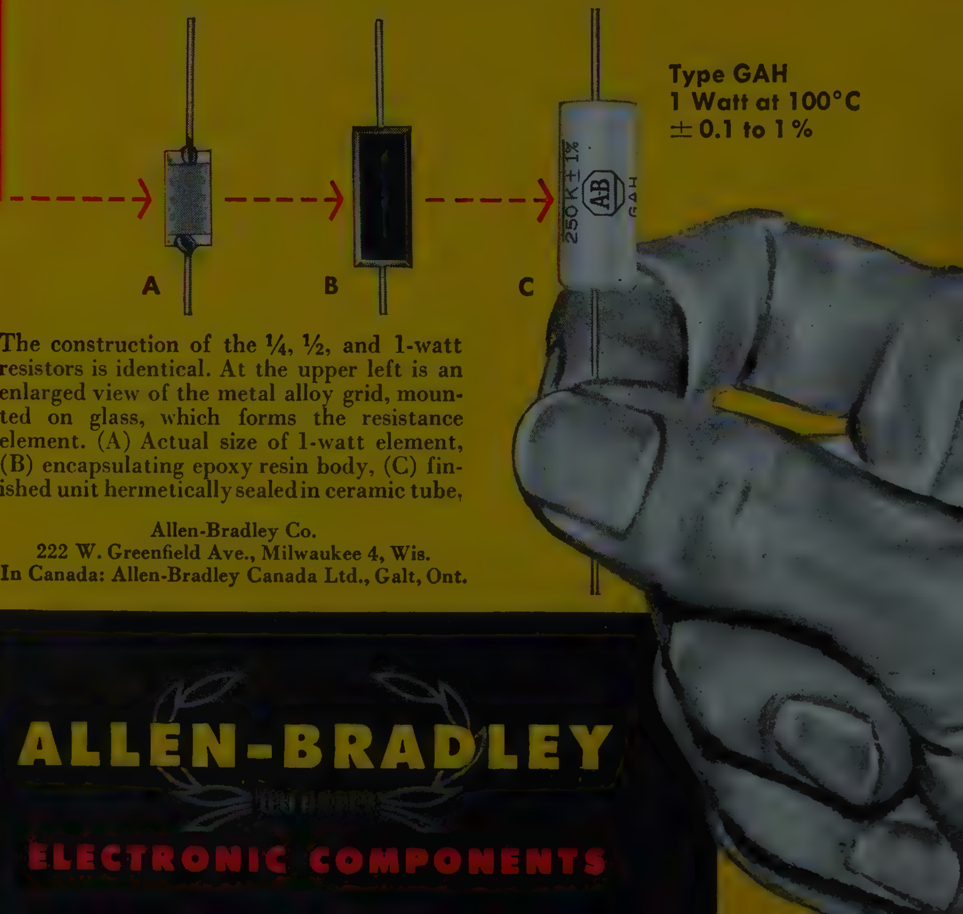
## PRECISION RESISTORS

A-B QUALITY



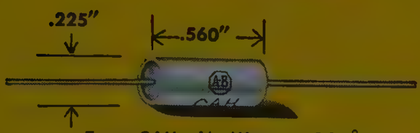
### *Far exceed MIL Specs for film and wire-wound resistors*

Allen-Bradley's new, truly accurate, metal grid resistors are now available in ¼, ½, and 1-watt ratings, producing test results that are a substantial improvement over the MIL Specifications for wire-wound and film type precision resistors. They combine remarkable stability, under load and on the shelf, with an exceptionally low temperature coefficient. The metal alloy grid is noninductive, providing excellent high frequency characteristics. They also have an exceptionally low noise level . . . comparable to that of wire-wound units. Each unit is individually calibrated and marked with nominal resistance value, tolerance (± 0.1 to 1%), and temperature coefficient. Provided with gold plated leads for flawless soldering. Considering their superior characteristics, these new resistors justly qualify under the Allen-Bradley trademark of *Quality.*

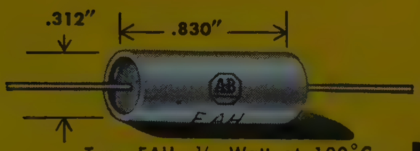


**Type GAH**
**1 Watt at 100°C**
**± 0.1 to 1%**

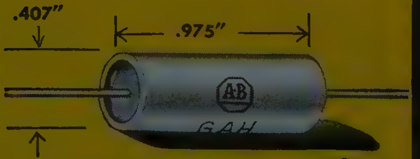
The construction of the ¼, ½, and 1-watt resistors is identical. At the upper left is an enlarged view of the metal alloy grid, mounted on glass, which forms the resistance element. (A) Actual size of 1-watt element, (B) encapsulating epoxy resin body, (C) finished unit hermetically sealed in ceramic tube.



Type CAH—¼ Watt at 100°C



Type EAH—½ Watt at 100°C



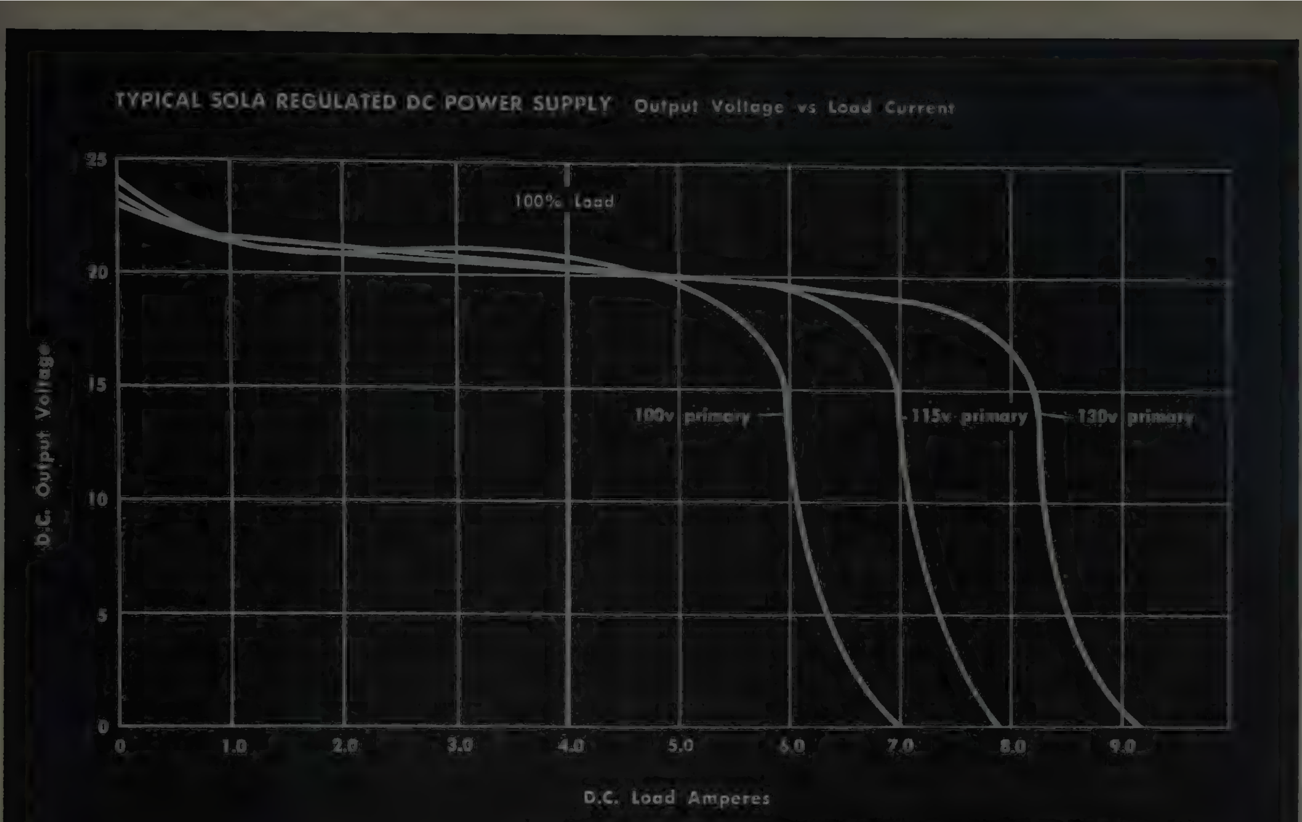
Type GAH—1 Watt at 100°C

Allen-Bradley Co.
222 W. Greenfield Ave., Milwaukee 4, Wis.
In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

**ALLEN-BRADLEY**

**ELECTRONIC COMPONENTS**

5-58-E



Curves covering output voltage of a Sola Constant Voltage DC Power Supply show flat regulation between 25% and 100% of rated load, and rapid drop to zero beyond — illustrating its current-limiting characteristic.

# RELIABLE, regulated DC power supply

Here's a regulated dc power supply that will protect its load and itself from a fault or short beyond the primary of its power transformer. If you're interested in a simple, reliable source of regulated dc power, you'll like the Sola Constant Voltage DC Power Supply.

This very desirable load protection characteristic results from the current-limiting action of the Sola Constant Voltage Transformer. It is combined with a semiconductor rectifier, and a high-capacitance filter. The current-limiting action protects both the rectifier and capacitors from damage by preventing excessive charging current.

This unique combination of components results in a power supply that is unusual in other ways as well. Regulation is within ±1% with up to 10% line voltage variation . . . ripple within 1% rms . . . efficiency is high. It's also well-suited for intermittent, variable, and pulse loads.

The Sola dc supply is reliable, simple, compact, and moderately-priced.

Fixed output — six ratings available from stock

Adjustable output — six ratings from stock

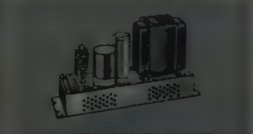
Custom-designed units produced to your specs

*Write for Bulletin IJ-DC-235*

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in Principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

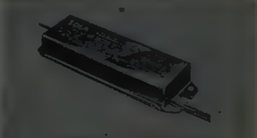
SOLA

CONSTANT VOLTAGE TRANSFORMERS



REGULATED DC POWER SUPPLIES

MERCURY LAMP TRANSFORMERS



FLUORESCENT LAMP BALLASTS

# IRE News and Radio Notes

## Calendar of Coming Events and Authors' Deadlines*

### 1958

**Symp. on Extend. Range and Space Commun., Lisner Audit., Geo. Wash. Univ., Washington, D. C., Oct. 6–7**

**IRE Canadian Convention, Exhibition Park, Toronto, Can., Oct. 8–10**

**Nat'l Electronics Conf., Hotel Sherman, Chicago, Ill., Oct. 13–15**

1958 Int'l Systems Meeting, Penn-Sheraton Hotel, Pittsburgh, Pa., Oct. 13–15

**PGCS Symp. on Aero. Communications, Hotel Utica, Utica, N. Y., Oct. 20–22**

**URSI Fall Meeting, Penn State Univ., Univ. Park, Pa., Oct. 21–22**

**Nat'l Simulation Conf., Dallas, Tex., Oct. 23–25**

Nat'l Soc. of Prof. Engrs., St. Francis Hotel, San Francisco, Calif., Oct. 23–25

**EIA-IRE Radio Fall Meeting, Sheraton Hotel, Rochester, N. Y., Oct. 27–29**

**East Coast Conf. on Aero. & Nav. Elec., Lord Baltimore Hotel and 7th Regiment Armory, Baltimore, Md., Oct. 27–28**

**1958 Electron Devices Meeting, Shoreham Hotel, Washington, D. C., Oct. 30–Nov. 1**

**PGNS Mtg., Villa Motel, San Mateo, Calif., Nov. 6–7**

**Atlanta Section Conf., Atlanta-Biltmore Hotel, Atlanta, Ga., Nov. 17–19**

**Conf. on Magnetism and Mag. Materials, Sheraton Hotel, Philadelphia, Pa., Nov. 17–20**

**NEREM, Mechanics' Bldg., Boston, Mass., Nov. 19–20**

**Conf. on Elec. Tech. in Med. and Biol., Nicollet Hotel, Minneapolis, Minn., Nov. 19–21 (DL*: Oct. 1, R. Erskine, Minneapolis-Honeywell, 2753 Fourth Ave., Minneapolis)**

**Acoustical Soc. of Amer., Chicago, Ill., Nov. 20–22**

Elec. Computer Exhibition, Olympia, London, Eng., Nov. 28–Dec. 4

EIA Conf. on Reliable Elec. Connections, Statler Hilton Hotel, Dallas, Texas, Dec. 2–4

**Eastern Joint Computer Conf., Bellevue-Stratford Hotel, Philadelphia, Pa., Dec. 3–5**

**Nat'l Symp. on Global Comm., Colonial Inn, Desert Ranch, St. Petersburg, Fla., Dec. 3–5**

**PGVC Annual Mtg., Hotel Sherman, Chicago, Ill., Dec. 4–5**

**Mid-Amer. Elec. Convention, Mun. Audit., Kansas City, Mo., Dec. 9–11**

### 1959

**Rel. & Qual. Control Nat'l Symp., Bellevue-Stratford Hotel, Philadelphia, Pa., Jan. 12–13**

**Solid-State Circuits Conf., Univ. of Pa., Philadelphia, Pa., Feb. 12–13 (DL*: Oct. 16, A. P. Stern, G. E. Co., Elec. Park, Bldg. 3, Syracuse, N. Y.)**

*DL = Deadline for submitting abstracts.

(*Continued on page 15A*)

## PGMIL PROCEEDINGS AVAILABLE

Conference Proceedings for the 1957 and 1958 National Conventions on Military Electronics can be ordered from IRE Headquarters at a price of $3.00 each for IRE members and $5.00 each for nonmembers. The Proceedings contain all unclassified papers presented at the Conventions, and abstracts of the classified papers.

Although emphasis was on missiles and the space age, nearly every phase of military electronics was treated at these Conventions. The list of session topics included: space vehicle electronics, guidance and control; reliability techniques and procedures; data handling systems and data links; ranging and tracking; reconnaissance and infrared systems; infrared detection, reconnaissance and fuzing systems; communication systems; inertial systems; simulation systems; and navigational systems.

The Convention Committees have announced that orders for these publications have been received from all regions of the United States, as well as from Sweden, England, Argentina, Israel, Mexico, Italy, Canada, and Germany.

## NEC ANNOUNCES SPEAKERS

Three luncheon speakers, representing the armed forces, the government, and private industry, have been announced for the National Electronics Conference, October 13–15, at the Hotel Sherman in Chicago.

Gen. John B. Medaris, commanding general, U. S. Army Ordnance Missile Command, Redstone Arsenal, Alabama, will speak on Monday, October 13.

Donald B. Quarles, Deputy Secretary of Defense for the United States, will address a luncheon audience on Tuesday.

Dr. Simon Ramo, vice-president of Ramo-Wooldridge Corporation, and President of its Space Technology Laboratories, will speak on Wednesday.

An attendance of over 10,000 is expected during NEC's three-day program.

## ADVANCE PUBLICATION FEATURE OF EIA DECEMBER MEETING

The Electronic Industries Association has announced that no technical papers will be read at its Conference on Reliable Electrical Connections in Dallas, Texas on December 2–4. Papers will be published in advance, with only summaries presented at the conference by the authors. Maximum time will be devoted to panel discussions and informal question and answer sessions.

Materials, methods, equipment, environment, and maintenance of electrical connection will be analyzed during the meeting.

R. George Roesch, 1068 S. Clinton Street, Syracuse 4, N. Y., General Chairman of the Conference, may be contacted for further information.

## Call for Papers

### 1959 IRE NATIONAL CONVENTION

**March 23–26, 1959**

**Waldorf-Astoria Hotel and New York Coliseum, New York, N. Y.**

Prospective authors are requested to submit all of the following information by:

**October 24, 1958**

1. 100-word *abstract in triplicate*, title of paper, name and address
2. 500-word *summary in triplicate*, title of paper, name and address
3. An indication of the technical field in which the paper falls:

Aeronautical & Navigational Electronics
Antennas & Propagation
Audio
Automatic Control
Broadcast & Television Receivers
Broadcast Transmission Systems
Circuit Theory
Communications Systems
Component Parts
Education
Electron Devices
Electronic Computers
Engineering Management
Engineering Writing & Speech
Human Factors in Electronics
Industrial Electronics
Information Theory
Instrumentation
Medical Electronics
Microwave Theory & Techniques
Military Electronics
Nuclear Science
Production Techniques
Radio Frequency Interference
Reliability & Quality Control
Telemetry & Remote Control
Ultrasonics Engineering
Vehicular Communications

Note: Only considered are original papers not published or presented prior to the 1959 IRE National Convention; any necessary military or company clearance of paper must be granted prior to submittal.

Address all material to:
Dr. George L. Haller, Chairman
1959 Technical Program Committee
The Institute of Radio Engineers, Inc.
1 East 79 Street, New York 21, N. Y.

During his recent visit to the Rome-Utica Section, Donald G. Fink (*second from right*), IRE President, was entertained at a banquet at Trinkhaus Manor, Oriskany, N. Y. Officers of the Section are (*left to right*): William J. Kuehl, Vice-Chairman; Reuben O. Schlegelmilch, Chairman; Robert A. Zachary, Secretary-Treasurer.

## MISCELLANEOUS IRE PUBLICATIONS AVAILABLE

**The following issues of miscellaneous publications are available from the Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, New York, at the prices listed below.**

| Meetings | Publications | Price per Copy |
|---|---|---|
| Component Symposia | *Proceedings of the 1954 Electronic Components Symposium,* held May 4–6, 1954 in Washington, D. C. | $4.50 |
| | *Proceedings of the 1957 Electronic Components Symposium,* held May 1–3, 1957 in Chicago, Ill. | 5.00 |
| Electronic Computer Conferences | *Proceedings of the Joint AIEE IRE ACM Eastern Conference,* held December 10–12, 1951 in Philadelphia, Pa. | 3.50 |
| | *Proceedings of the Joint AIEE IRE ACM Eastern Conference,* held December 8–10, 1954 in Philadelphia, Pa. | 3.00 |
| | *Proceedings of the Joint AIEE IRE ACM Eastern Conference,* held November 7–9, 1955 in Boston, Mass. | 3.00 |
| | *Proceedings of the Joint AIEE IRE ACM Eastern Conference,* held December 10–12, 1956 in New York, N. Y. | 3.00 |
| | *Proceedings of the Joint AIEE IRE ACM Eastern Conference,* held December 9–13, 1957 in Washington, D. C. | 3.00 |
| | *Proceedings of the Joint AIEE IRE ACM Western Conference,* held March 1–3, 1955 in Los Angeles, Calif. | 3.00 |
| | *Proceedings of the Joint AIEE IRE ACM Western Conference,* held February 7–9, 1956 in San Francisco, Calif. | 3.00 |
| | *Proceedings of the Joint AIEE IRE ACM Western Conference,* held February 26–28, 1957 in Los Angeles, Calif. | 4.00 |
| Magnetic Amplifiers Conference | *Proceedings of the Conference on Magnetic Amplifiers,* held April 5–6, 1956 in Syracuse, N. Y. | 4.00 |
| Medical Electronics Bibliography | *Bibliography on Medical Electronics,* June, 1958 | 2.50 |
| Military Electronics Convention Records | *Proceedings of the First National Convention,* held June 17–19, 1957 in Washington, D. C. | 5.00* |
| | *Proceedings of the Second National Convention,* held June 16–18, 1958 in Washington, D. C. | 5.00† |

* IRE-PGMIL rate $3.00.
† IRE Member rate $3.00.

(*Continued on page 16A*)

## Calendar of Coming Events and Authors' Deadlines*

(*Continued from page 14A*)

Western Joint Computer Conf., Fairmont Hotel, San Francisco, Calif., Mar. 3–5 (DL*: Oct. 1, M. L. Lesser, IBM Research Lab., San Jose, Calif.)

IRE Nat'l Convention, Coliseum and Waldorf-Astoria, New York City, Mar. 23–26

Silicon-Carbide Conf., Boston, Mass., Apr. 2–3 (DL*: Mar. 1, J. R. O'Connor, Elec. Matl. Sci. Lab., AF Cambridge Res. Ctr., Bedford, Mass.)

Nuclear Cong., Cleveland, Ohio, Apr. 5–10

SWIRECO (Southwestern Regional Conference), Dallas, Texas, Apr. 16–18 (DL*: Nov. 1, Frank Seay, Texas Instr. Inc., 6000 Lemmon Ave., Dallas 9, Tex.)

New Tech. in Elec. Indus. Instrumentation, Philadelphia, Pa., Apr. 20–21

Nat'l Aero. Elec. Conf., Dayton, Ohio, May 4–6

Fifth Annual Flight Test Instr. Symp., Seattle, Wash., May 4–7

URSI Spring Meeting, Washington, D. C., May 5–7

Elec. Components Conf., Ben Franklin Hotel, Philadelphia, Pa., May 6–8 (DL*: Oct. 1, Brig. Gen. E. R. Petzing, AGEP Secretariat, Univ. of Penn., 200 S. 33 St., Phila., Pa.)

7th Reg. Tech. Conf., Univ. of N. M., Albuquerque, N. M., May 6–8

Joint Conf. on Auto. Tech., Pick-Congress Hotel, Chicago, Ill., May 11–13

Internatl. Conv. on Transistors and Associated Semiconductor Devices, Earls Court, London, May 25–29

Internatl. Conf. on Med. Elec., Paris, France, June

Prod. Tech. Symp., Villa Hotel, San Mateo, Calif., June 4–5

Int'l Conf. on Info. Processing, UNESCO House, Paris, France, June 15–20 (DL*: Oct. 1, A. S. Householder, Oak Ridge Nat'l Lab., Oak Ridge, Tenn.)

Natl. Conv. on Mil. Elec., Sheraton Park Hotel, Washington, D. C., June 29–July 1

WESCON, San Francisco, Calif., Aug. 18–21

Natl. Symp. on Telemetering, San Francisco, Calif., Sept.

IRE Canadian Conv., Toronto, Can., Oct. 7–9

Natl. Elec. Conf., Hotel Sherman, Chicago, Ill., Oct. 12–15

East Coast Conf. on Aero. and Nav. Elec., Baltimore, Md., Oct. 26–28

Electron Devices Mtg., Shoreham Hotel, Washington, D. C., Oct. 29–31

Natl. Conf. on Automatic Control, New Sheraton Hotel, Dallas Tex., Nov. 4–6

Radio Fall Mtg., Syracuse, N. Y., Nov. 9–11

Eastern Joint Comp. Conf., Hotel Statler, Boston, Mass., Nov. 30–Dec. 3

* DL = Deadline for submitting abstracts.

Members of the Executive Committee met recently to plan the October IRE Aero-Com Symposium. (*Front row, left to right*) T. G. Knight, Classified Sessions Chairman; George Baldwin, Finance Chairman; H. J. Crowley, Symposium Chairman; W. L. Roberts, Secretary; J. H. Vogelman, Scholarship Fund Chairman. (*Back row, left to right*) B. H. Baldridge, Guest Speakers Chairman, F. R. Priest, Arrangements Chairman; A. A. Kunze, Advisory Staff member; R. C. Benoit, Jr., Public Relations Chairman; R. A. Zachary, Executive Vice-Chairman; J. W. Worthington, Jr., PGCS National Chairman.

## MISCELLANEOUS IRE PUBLICATIONS AVAILABLE

| Meetings | Publications | Price per Copy |
|---|---|---|
| Reliability and Quality Control in Electronics Symposia | *Proceedings of the 1st National Symposium on Quality Control and Reliability in Electronics,* held November 12–13, 1954 in New York, N. Y. | 5.00 |
| | *Proceedings of the 2nd National Symposium on Quality Control and Reliability in Electronics,* held January 9–10, 1956 in Washington, D. C. | 5.00† |
| | *Proceedings of the 3rd National Symposium on Reliability and Quality Control in Electronics,* held January 14–16, 1957 in Washington, D. C. | 5.00 |
| | *Proceedings of the 4th National Symposium on Reliability and Quality Control in Electronics,* held January 6–8, 1958 in Washington, D. C. | 5.00 |
| Telemetering Conference | *Proceedings of the 1953 National Telemetering Conference,* held May 20–22, 1953 in Chicago, Ill. | 2.00 |

† IRE Member rate $3.00.

## Army MARS Broadcasts Listed

The October schedule of programs for the Army MARS technical network, operating at 4030 kc upper sideband on Wednesday evenings at 9 P.M., has been announced as follows.

October 1—"Engineering the White Alice Network," Robert B. Stecker, Defense Projects Division, Western Electric Co.

October 8—"Characteristics of SSB Power Amplifier Circuits," Warren B. Breune, Technical Consultant, Collins Radio Co.

October 15—"Technical Facilities of Radio Free Europe," Claude M. Harris, Director of Engineering, Radio Free Europe.

October 22—"Application of Transistors to Power Supply Equipment," Sidney Moskowitz, Vice-President, Electronic Research Associates, Inc.

October 29—"Maser Amplifiers and Oscillators," Gerhard Weibel, Head of Submillimeter Research Section, Sylvania Electric Products Co., Inc.

## WJCC Scheduled for March

The 1959 Western Joint Computer Conference has been set for March 3–5 in San Francisco's Fairmont Hotel, according to Robert R. Johnson, general chairman. Joint sponsors are IRE, AIEE, and ACM.

"New Horizons with Computer Technology" has been selected as the general theme of the three-day meeting. Murray L. Lesser, chairman of the Technical Program Committee, has stated that there will be "particular emphasis on factual papers dealing with the newer applications of computer techniques, such as Information Retrieval, Operation Control, Pattern Analysis, Decision Making, Computer Communications and Learning Concepts, as well as on papers dealing with advances in computer component and systems design."

Correspondence concerning the conference should be addressed to Box 381, Station A, Palo Alto, Calif.

## AF Cambridge Center Plans Silicon Carbide Conference

A conference on silicon carbide, the new semiconductor, is scheduled at Boston, Mass., April 2–3, 1959, under the auspices of the Air Force Cambridge Research Center. The conference will consider the preparation, properties, and applications of silicon carbide, and will aim to consolidate efforts on its research and development.

Abstracts of technical papers will be accepted until December 1, 1958. These should be 200 words or less, and should be included in one of the following subject divisions: growing of single crystals of silicon carbide by sublimation and from melts; physical properties of silicon carbide as a solid; measurement of electronic and optical properties; applications for active devices, diodes, thermoelements, etc.

The program will also feature invited papers and reports of recent developments. Further information may be obtained from J. R. O'Connor, Electronic Material Sciences Laboratory, Air Force Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass.

## Broadcasting Schedule Announced for AF Mars

The Air Force MARS Eastern Technical Net, which broadcasts over the air every Sunday afternoon at 2 P.M. (EST) on 3295, 7540, and 7635 kc, announces the following programs:

October 5, 12—"Transistor Fundamentals," Panel of engineers from Philco Corp. Transistor Laboratory.

October 19—"Information Theory," John Pierce, Bell Telephone Laboratories.

October 26—"Satellite Tracking at the Yale Observatory," James Douglas, Yale University.

November 2—"Radio Traffic Control," Commissioner T. T. Wiley & panel, N. Y. C. Department of Traffic.

November 9—"Sourcing and Curing Radio Interference," Harry Wallace, Consulting Engineer.

## USSR Scientific Journals Now Available in English

Approximately 60,000 pages a year of key Soviet scientific and technical journals are now available in English translation to United States scientists and engineers, the National Science Foundation has announced. In releasing a compilation of translated Russian journals, the Foundation indicated that there are now in print 53 English editions of Russian journals, 4 extensive series of trans-

(*Continued on page 18A*)

# The Great Dragon Raid of 1405

*Legend has it that one balmy spring afternoon in 1405, during the Ming Dynasty, a flight of dragons, cruising at low altitude, swooped down and demolished all the radar stations posted along the Great Wall of China.*

*Thus, the first DEW line (Dragon Early Warning) in history was pulverized at a stroke. But Emperor Ming, who had spared no expense in building his dragon-net, had the last laugh.*

*True, not a single antenna remained standing. Every last one was eaten to the last savory shoot by the bamboo-loving dragons.*

*However, not a single dragon survived his meal. Every last savory bamboo shoot had been poisoned by the Emperor, who obviously didn't put all his trust in electronics . . . as who would in 1405 B.B. (Before Bomac)?**

*Moral: There are more ways than one to bamboozle dragons.*

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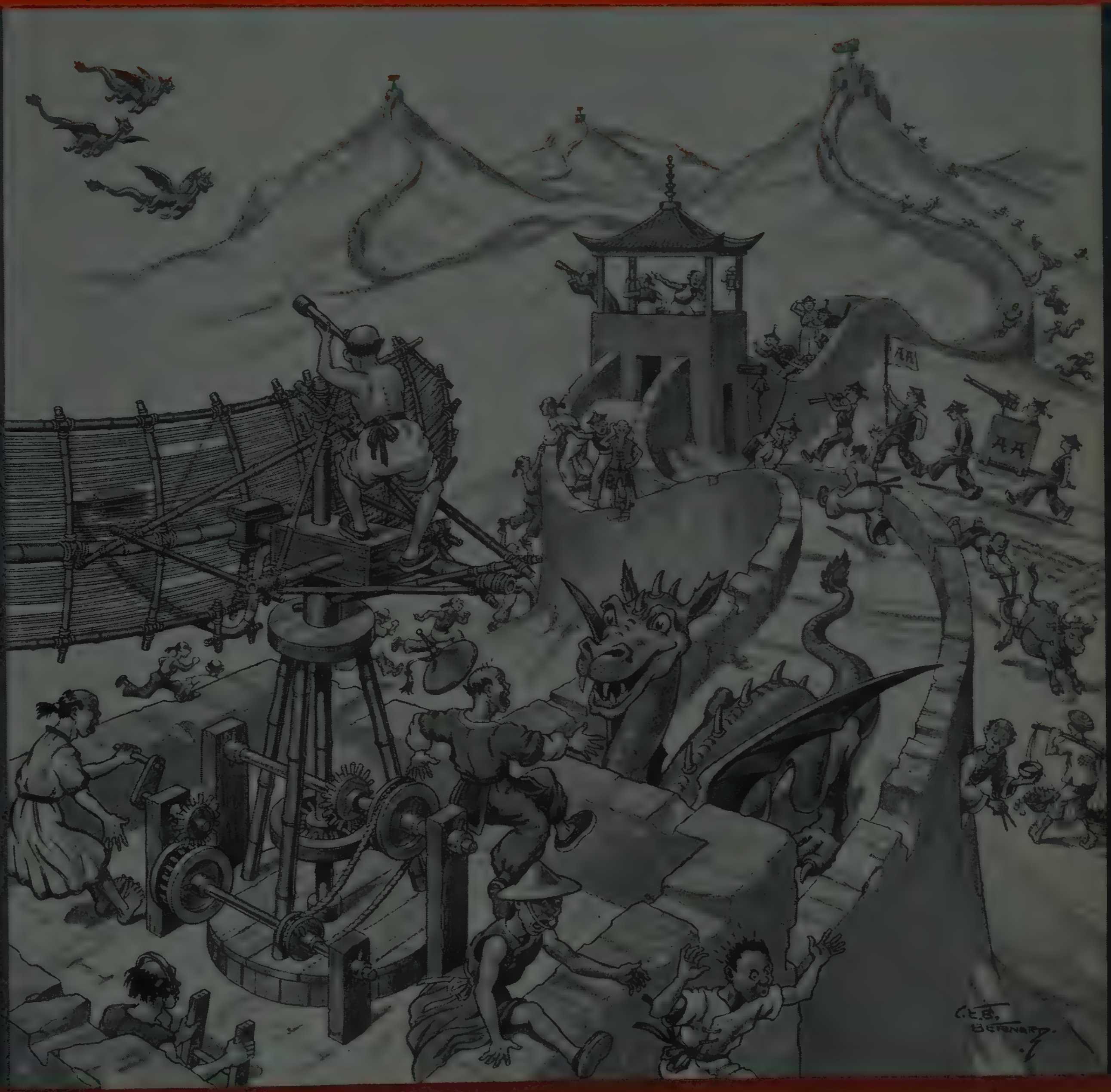

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## USSR SCIENTIFIC JOURNALS AVAILABLE

| Journal | Where to Order | Subscription Price Per Year |
|---|---|---|
| *Journal of Technical Physics* (*Zhurnal Teknicheskoi Fiziki*) monthly | American Institute of Physics, 335 E. 45 St., N. Y. 17, N. Y. | $75.00<br>35.00[1] |
| *Acoustics Journal* (*Akusticheskii Zhurnal*) quarterly | American Institute of Physics, 335 E. 45 St., N. Y. 17, N. Y. | $12.00 |
| *Proceedings of the USSR Academy of Sciences* (*Doklady Akademii Nauk SSSR*) bimonthly, physics sections | American Institute of Physics, 335 E. 45 St., N. Y. 17, N. Y. | $35.00<br>15.00[1] |
| *Journal of Experimental and Theoretical Physics* (*Zhurnal Eksperimental'noi i Teoreticheskoi*) monthly. (Translation journal known as *Soviet Physics—JETP*) | American Institute of Physics, 335 E. 45 St., N. Y. 17, N. Y. | $60.00[2]<br>75.00[3]<br>35.00[1] |
| *Instruments and Experimental Techniques* (*Pribory i Tekhnika Eksperimenta*) bimonthly | Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa. | $25.00<br>12.50[1] |
| *Measurement Techniques* (*Ismeritel'naya Tekhnika*) bimonthly | Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa. | $25.00<br>12.50[1] |
| *Radio Engineering* (*Radiotekhnika*) monthly | (Administered by M.I.T.) Pergamon Press, Ltd., 122 E. 55 St., N. Y. 22, N. Y. | $15.00<br>30.00[4] |
| *Radio Engineering and Electronics* (*Radiotekhnika i Elektronika*) monthly | (Administered by M.I.T.) Pergamon Press, Ltd., 122 E. 55 St., N. Y. 22, N. Y. | $22.50<br>45.00[4] |
| *Electro-Communications* (*Elektrosviaz*) monthly | (Administered by M.I.T.) Pergamon Press, Ltd., 122 E. 55 St., N. Y. 22, N. Y. | $15.00<br>30.00[4] |
| *Automation and Remote Control* (*Avtomatika i Telemekanika*) monthly | (Administered by M.I.T.) Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa. | $30.00<br>15.00[1] |
| *Bulletin of the Academy of Sciences, USSR: Physics Series* (*Izvestiia Akademii Nauk SSSR: Seriia Fiziki*) monthly | Columbia Technical Translations, 5 Vermont Ave., White Plains, N. Y. | $215.00 |
| *Proceedings of the Academy of Sciences of the USSR* (*Doklady Akademii Nauk SSSR*)<br>*Applied Physics Section* (*Otdel Prikladnoi Fiziki*) bimonthly | Consultants Bureau, Inc., 227 W. 17 St., N. Y. 11, N. Y. | $200.00 |

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[1] Price per year to libraries of educational institutions.
[2] Renewal price.
[3] New subscription price.
[4] Price per year to libraries.

lated Russian abstracts of scientific papers, and 4 series of partial translations of important Russian journals.

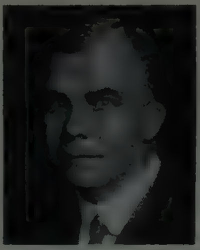
Support of these translations is provided by Government agencies—the National Science Foundation, the National Institutes of Health, the Office of Naval Research, and the Atomic Energy Commission (the latter two working through the National Science Foundation)—and by six commercial translating and publishing firms working without Government funds.

Foundation-supported translation projects, continually increasing in number, are conducted by United States professional scientific societies and university groups which have chosen the Russian material to be translated and which have requested the financial support of the Foundation. These organizations administer their own projects and provide expert consultation to translators to help insure accuracy. The translations are sold on a subscription basis with the resulting income used to defray part of the costs of the projects, thus reducing the need for Government support.

The above compilation is a partial list of translated journals covering fields of possible interest to IRE members. A complete list of journals in all fields has been compiled by the National Science Foundation, Washington 25, D. C.

## OBITUARIES

**Henry E. Hallborg** (A'12–M'14–F'27–L) died recently at the age of 74. He was an engineering research consultant at the time of his death.


H. E. HALLBORG

Mr. Hallborg was born in Stockholm, Sweden on April 24, 1884. He received the B.S.E.E. degree from Brown University, Providence, R. I. in 1907.

From 1909 to 1911 he was employed by National Electric Signaling Company, Brant Rock, Mass. He joined Marconi Wireless Telegraph Company in 1911 and for four years was engineer-in-charge of its high-power stations at Belmar and New Brunswick, N. J. From 1915 to 1923 he was associated with the Navy Department as an expert radio aid in Norfolk, Va., and Washington, D. C., and from 1923 to 1925 he was a consulting engineer for C. Brandies Company, New York, N. Y. Mr. Hallborg joined RCA Communications, Inc. in 1925.

He was a member of the IRE Committee on Constitution and Bylaws, the Technical Committee on Radio Transmitters and Antennas, and the Standards Committee.

**George Braxton Pegram** (A'12–VA'39–M'55–L), a leading physicist in atomic energy research, died recently in Pennsylvania at the age of 81. He had been associated with Columbia University from 1900, when he was appointed an assistant in physics, until 1957, the date of his retirement as vice-president emeritus and advisor to the president. As Dean of Graduate Faculties, he was instrumental in persuading Dr. Enrico Fermi, Italian nuclear physicist, and Dr. John R. Dunning to continue at Columbia the experiments which achieved in 1939 the first successful demonstration of uranium fission in this country.

Dr. Pegram was born on October 24, 1876, in Trinity, N. C. He graduated from Trinity College, now Duke University, in 1895 and entered Columbia five years later. His dissertation for the Ph.D. degree in 1903 was one of the earliest studies of radioactivity in the United States. As a Tyndall Fellow, he studied at the University of Berlin under Max Planck, and at Cambridge University in England during 1907 and 1908.

Among his scientific contributions was the co-invention, with Dr. Dunning, of a devicefor measuring the component parts of the atom and for demonstrating the possibility of transmuting one element into another.

During World War II he was vice-chairman of the Central Advisory Committee to the Manhattan Engineering District. After the war he was on the first board of directors of Oak Ridge National Laboratory, Tenn., and helped to establish Brookhaven National Laboratory, on Long Island.

Dr. Pegram received seven honorary doctorate degrees. He was a past president of the New York Academy of Sciences and of the American Physical Society, and a past chairman of the Anglo-American-Hellenic Bureau of Education. In 1957 he was awarded the first Karl Taylor Compton Gold Medal from the American Institute of Physics.

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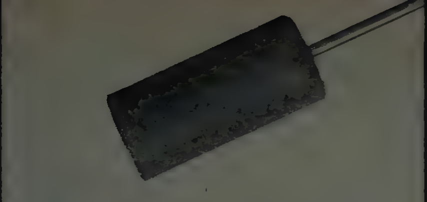
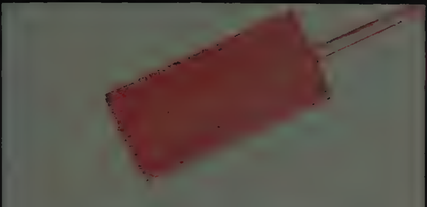
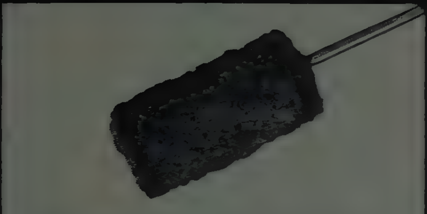
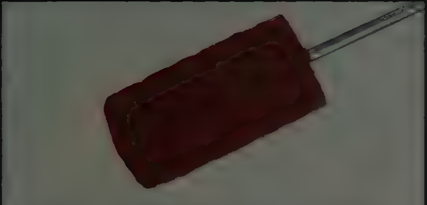
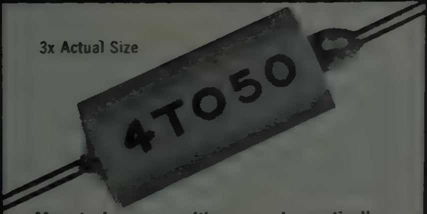

High capacitance value in small package provided by TI precision formed pellet.

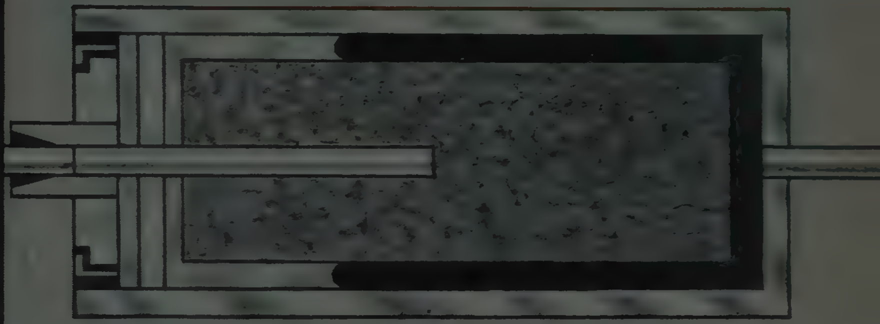

Safe dielectric stress is determined by anodized coating of tantalum pentoxide.


Solid $MnO_2$ electrolyte cannot leak.


Positive bond to solder base for cathode connection assured by copper coating.



Mounts in any position . . . hermetically sealed, metal case is shock resistant.



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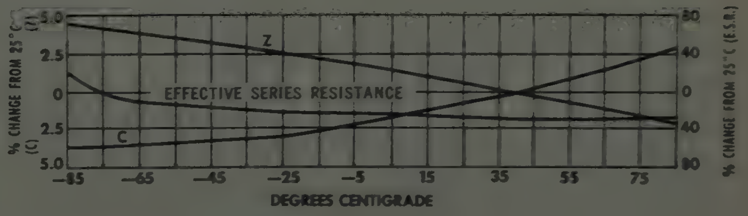
| 15-Volt | 10 | 15 | 22 | 33 | 100 |
| 25-Volt | 5 | 10 | 15 | 35 | 55 |
| 35-Volt | 4 | 8 | | | |



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# Fourth Annual Symposium on Aeronautical Communications

October 20–22, Hotel Utica, Utica, N. Y.

The Fourth National Aero-Com Symposium, sponsored by the Professional Group on Communications Systems, will be held at the Hotel Utica, Utica, N. Y. on October 20 and 21. In addition, a one-day classified symposium will be held on October 22 at Griffiss Air Force Base, Rome, N. Y., under the auspices of the Directorate of Communications, Rome Air Development Center. Participation in the classified session will be limited to those possessing a current Confidential security clearance.

This year's Symposium will stress the requirements, progress, and challenge of communications in all its phases in the Space Age. Technical papers and product exhibits will be devoted to enlarging these general topics.

A banquet, luncheon, and Industry-sponsored cocktail party have been included in the two-day meeting. Advance registration fee is $1.00 and registration at the Symposium is $2.00.

### Monday Morning, October 20

### Communications Media and Equipments

*Propagation of VHF in the Arctic Region*, R. Penndorf and S. C. Coroniti, Avco.

*Prediction of Radio Transmission Loss Above 40 MC/SEC*, P. L. Rice, A. G. Longley, and K. A. Norton, Natl. Bur. of Standards.

*Cross Modulation by Rectification*, C. E. Young, U. S. Naval Research Lab.

*Analysis of SSB Power Amplifier*, F. Assadourian, RCA.

*Klystron Power Amplifier Performance*, J. B. Murray, E. A. Worrell, and L. P. Yey, Westinghouse.

### Monday Afternoon

### Communications Media and Equipments

*Pulse Phase-Change Signalling in Presence of Ionospheric Multipath Distortion*, S. G. Lutz, Hughes.

*A Very High-Speed Facsimile Recorder*, M. Stamps and H. C. Ressler, Hogan Labs.

*A New Airborne Digital Selective Calling System*, M. Cooper, Motorola, Inc.

*A General Purpose Air-Ground Communication Link*, W. F. Walker and W. J. Stolze, Stromberg-Carlson.

*An Analog Computer for Finding an Optimum Route Through a Communications Network*, H. Rapaport and P. Abramson, RCA.

### Tuesday Morning, October 21

### Communications Systems

*Synthesis of Tactical Communication Systems*, R. J. Meyer, RCA.

*Calculation of Path Loss for Beyond Horizon Radio Systems and Experimental Confirmation*, S. C. Fritsch, Western Electric.

*Interference to UHF Communications Systems*, R. O. Schildknecht, ITT Labs.

*Data Transmission Tests on Tropospheric Beyond Horizon Radio Systems*, F. E. Willson and W. A. Runge, Jr., Bell Labs.

*Two Analytical Methods to Save Costs in Communications Systems Planning*, R. Krzyczkowski, Westinghouse.

### Tuesday Afternoon

### Space Communications

*Introduction to Space Communication Systems Design*, L. P. Yeh, Westinghouse.

*Doppler Phenomena in Space Communications*, F. J. Tischer, Ohio State Univ.

*Communication Between Space Vehicles and Polar Locations*, W. D. Stuart and L. C. Kelley, U. S. Army Signal Radio Propagation Agency.

*Coexistence of Celestial and Terrestrial Communication*, S. G. Lutz, Hughes.

*Communication During Hypersonic Re-Entry*, E. Langberg, Avco.

# URSI Fall Meeting

October 21–22, Pennsylvania State University, University Park, Pa.

### Tuesday Morning, October 21

Registration

### Combined Technical Session

*Chairman:* W. E. Gordon.

*Welcome:* Dean M. A. Williamson, School of Engineering and Architecture, Pennsylvania State Univ.

*Statistical Methods in Radio Wave Propagation*, W. C. Hoffman, RAND Corp.

*On Scattering of Waves by Random Distribution of Tenuous Objects*, V. Twersky, Sylvania Electronic Defense Lab.

*Aeronomic Conditions in the Thermosphere*, M. Nicolet, Ionosphere Res. Lab., Pennsylvania State Univ.

*Developments in Radio Astronomy as Shown by the Paris-Moscow Meetings*, K. M. Siegel and F. T. Haddock, Univ. of Mich.

### Tuesday Afternoon

### Commission II—Tropospheric Structure and Motions

*Chairman:* M. C. Thompson, Jr.

*Propagation Characteristics of 2.5-MM Radio Waves*, C. W. Tolbert, C. O. Britt, and A. W. Straiton, Univ. of Tex.

*Mean-Squared-Error of a Band-Limited Long Line-of-Sight Radio Link Affected by Atmospheric Turbulence*, D. S. Bugnolo, Columbia Univ.

*The Phase Instability in a Microwave Ground Link*, R. N. Ghose, Ramo-Wooldridge Corp.

*Tropospheric Motions Observed in Rapid Beam-Swinging Experiments*, A. T. Waterman, Jr., Stanford Electronics Labs., Stanford Univ.

*Power Spectra of Temperature, Humidity, and Refractive Index from Tethered Balloon Measurements*, E. E. Gossard, U. S. Navy Electronics Lab.

*Radar Terrain Cross Section at Microwave Frequencies*, D. R. Bianco and C. S. Morris, Applied Physics Lab., The Johns Hopkins Univ.

### Commission III—Symposium on the Use of Space Vehicles

*Moderator:* A. H. Shapley, Natl. Bur. of Standards.

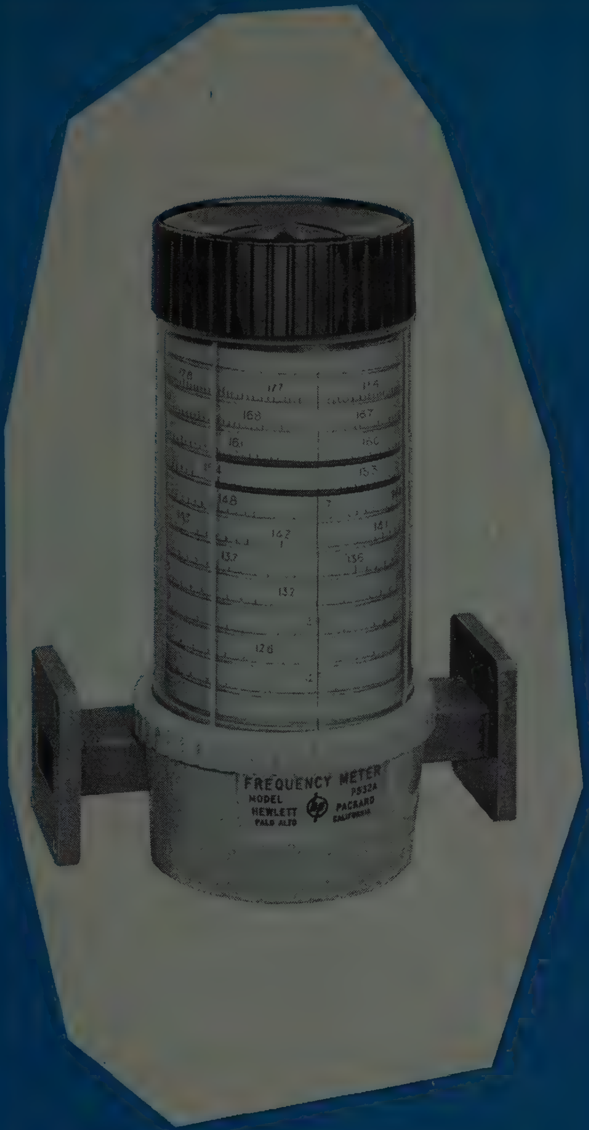
*Panel:* To be announced.

### Commission IV

*Chairman:* A. D. Watt.

*Precipitation Static on Modern Aircraft*, P. W. Couch, WADC.

*On the Electrostatic Theory of Lightning Discharges*, H. W. Kasemir, U. S. Army Signal Engineering Labs.



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| **Resetability:** | 0.01% | 0.01% | 0.01% | 0.01% |
| **SWR at resonance (approximate):** | 1.3:1 | 1.3:1 | 1.3:1 | 1.3:1 |
| **Price:** | $150.00 | $210.00 | $230.00 | $250.00 |

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*Amplitude-Probability Distribution Measurements of Atmospheric Radio Noise from 13 KC to 20 MC*, W. Q. Crichlow, C. J. Roubique, and W. M. Beery, Natl. Bur. of Standards.

*A Graphical Method of Obtaining Amplitude-Probability Distributions from Statistical Moments of Atmospheric Radio Noise*, W. Q. Crichlow and A. D. Spaulding, Natl. Bur. of Standards.

*Some Unusual Features of the Tornado Oscillator that Accompanied the Blackwell Tornado*, H. L. Jones, Oklahoma State Univ.

*Recent Results from the Whistler-West IGY Program*, R. A. Helliwell, J. H. Crary, R. L. Smith, and W. T. Kreiss, Stanford Univ.

*Propagation of Electromagnetic Waves Along a Columnar Ionic Irregularity*, F. H. Northover, Carleton Univ., Ottawa.

### Wednesday Morning, October 22

### Commission II—Beyond-the-Horizon Propagation

*Chairman:* J. H. Chisholm.

*Effect of Antenna Beamwidth and Upper-Air Wind Velocity on Fading on 4 KMC Waves Propagated Beyond the Horizon*, D. C. Hogg and L. R. Lowry, Bell Telephone Labs., Holmdel, N. J.

*Comparison of Short-Term Fading at 4110 and 460 MC in Propagation Beyond the Horizon*, D. C. Hogg and L. R. Lowry, Bell Telephone Labs., Holmdel, N. J.

*Propagation into the Twilight Region by Guided Modes Contained in the Normal Air by Partial Reflections*, T. J. Carroll and R. M. Ring, AFCRC.

*Spectral Analysis of Dual Frequency Multi-Range Beyond-the-Horizon Microwave Scattered Fields*, N. R. Ortwein, U. S. Navy Electronics Lab.

*Dual-Frequency Multi-Range Overwater Measurements of Beyond-the-Horizon Microwave Scattered Field Strength*, R. U. F. Hopkins, U. S. Navy Electronics Lab.

*Sweep-Frequency Studies in Beyond-the-Horizon Propagation*, W. H. Kummer, Bell Telephone Labs.

*Reciprocity and Scattering by Rough Surfaces*, W. S. Ament, Naval Res. Lab.

### Commission III—Ionospheric Structure and Propagation

*Chairman:* L. A. Manning.

*Early Results from the Equatorial Close-Spaced Chain of Vertical Sounding Stations*, R. W. Knecht and D. W. Schlitt, Natl. Bur. of Standards.

*Study of Vertical Drift in the F Region from True Height Profiles*, S. Chandra, J. J. Gibbons, and E. R. Schmerling, Ionosphere Res. Lab., Pennsylvania State Univ.

*Some Effects of Strong Blast Waves upon the Ionosphere*, F. B. Daniels and A. K. Harris, U. S. Army Signal Res. and Development Lab.

*Rocket Studies of the Arctic Ionospheric*, J. C. Seddon and J. E. Jackson, Naval Res. Lab.

*A Versatile Computer Program for Obtaining Refractive Indices and Polarizations from the Appleton-Hartree Equations*, E. A. Mechtly, L. M. Meixsell, and J. J. Gibbons, Ionosphere Res. Lab., Pennsylvania State Univ.

*Coefficients for the Rapid Reduction of h'-f Records to N-h Profiles without Computing Aids*, C. A. Ventrice and E. R. Schmerling, Ionosphere Res. Lab., Pennsylvania State Univ.

*Prediction of Lower Frequency Limits for F-Layer Oblique Transmissions by Direct Ray and by Pedersen Ray*, B. Fulton, O. Sandoz, and E. Warren, Defence Res. Telecommun. Establishment, Defence Res. Board, Ottawa, Can.

*The Oblique Propagation of Long and Very Long Waves—Abnormal Phenomena Associated with Great Geomagnetic Storms*, J. S. Melrose, Defence Res. Telecommun. Establishment, Defence Res. Board, Ottawa, Can.

### Commission VI—Radio Waves and Circuits; Information and Circuit Theory

*Chairman:* W. D. White.

*Geometric-Analytic Theory of Transition in Electrical Engineering*, E. F. Rolinder, AFCRC.

*Inductive Probability in Radar and Communications*, L. S. Schwartz, College of Engineering, N.Y.U.

*Capacity of Channels with Memory*, G. H. Myers, Bell Telephone Labs.

*On the Identity of Absolute Capacity and Ergodic Capacity of a Discrete Stationary Channel with Finite Memory*, S. S. L. Chang, College of Engineering, N.Y.U.

*Some Practical Aspects of Signal-Compression Coding*, A. E. Laemmel, Polytechnic Inst. of Brooklyn.

*On Synthesis of Information Networks*, R. Ash, Columbia Univ.

*Proofs of Some Network Theorems by Topological Formulas*, S. L. Hakimi and W. Mayeda, Univ. of Ill.

### Wednesday Afternoon

*The Time is Now*, Luncheon Address, E. A. Walker, President, Pennsylvania State University.

### Commission III—Scattered Signals

*Chairman:* M. G. Morgan.

*Angular Scintillations of Cassiopeia*, B. Nichols and J. L. Rosson, Cornell Univ.

*Observations of the Zenith Angle Dependence of Radio Star Scintillations at Manchester, England and College, Alaska*, C. G. Little, Geological Inst., Univ. of Alaska (now at Natl. Bur. of Standards).

*Comparison of Phase and Amplitude Radio-Star Scintillations with other Ionospheric Phenomena*, R. S. Lawrence, Natl. Bur. of Standards.

*Incoherent Scattering of Radio Waves by Free Electrons with Applications to Space Exploration by Radar*, W. E. Gordon, Cornell Univ.

*A Theory of Electrostatic Fields in a Non-Homogeneous, Non-Isotropic Conducting Medium, with Application to the Ionosphere*, D. Farley, Jr., Cornell Univ.

*Evidence for a 200 MC Ionospheric Forward Scatter Mode Associated with the Earth's Magnetic Field*, J. L. Heritage, S. Weisbrod, and W. J. Fay, Smyth Res. Associates.

*The Simultaneous Observation of Meteor Echoes over a 1250-KM Path at Two VHF Frequencies*, M. L. Meeks, J. C. James, and J. B. Berry, Georgia Inst. Tech.

*Wave Propagation Through Ionized Gases*, F. J. Tischer, Ohio State Univ.

### Commission IV—Symposium

*Discussion Leaders:* W. Q. Crichlow and R. A. Helliwell.

*Main Topics:* 1) Special URSI report on the characteristics of noise that cause interference to the reception of the signals; 2) The nomenclature and definitions in the field of VLF noise.

### Commission VI—Antennas

*Chairman:* D. D. King.

*A Surface Wave Antenna Paradox*, F. J. Zucker and A. F. Kay, AFCRC and Technical Res. Group, Inc.

*Four-Dimensional Antenna Systems*, H. E. Shanks and R. W. Bickmore, Hughes Aircraft Co.

*A Reciprocity Relation for Non-Periodic Fields*, G. Goubau, U. S. Army Signal Engineering Labs.

*The Far Fields Excited by a Point Source in a Dissipationless Passive Anisotropic Uniform Waveguide*, A. D. Bresler, Polytechnic Inst. of Brooklyn.

*Reflector Antenna Polarized Radiation*, L. E. Raburn, General Electric Co.

*High-Frequency Diffraction of Electromagnetic Waves by a Circular Aperture in an Infinite Plane Conducting Screen*, S. R. Seshadri and T. S. Wu, Gordon McKay Lab. of Applied Science, Harvard Univ.

* * *

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**INDICATING SYSTEM:** Large 5″ cathode ray tube, calibrated in % Q on the vertical axis and % L-C on the horizontal axis.

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**Q RANGE:** 50 to 500

**INDUCTANCE RANGE:** 1 Microhenry to 10 Millihenries.

**CAPACITANCE RANGE:** 2 MMF. to 1000 MMF.

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*Write for complete information*

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# National Simulation Conference

OCTOBER 23–25, STATLER-HILTON HOTEL, DALLAS, TEX.

### Thursday Morning, October 23

*Chairman:* F. W. Tatum, Elec. Eng. Dept., Southern Methodist Univ.

*Operational Analog Simulation of the Vibration and Flutter of a Rectangular Multicellular Structure*, A. B. Clymer, North American Aviation, Inc.

*Distributed Parameter Vibration with Structural Damping and Noise Excitation*, R. Powell, Jet Propulsion Lab., Calif. Inst. Tech.

*A Non-Real-Time Simulation of SAGE Tracking and BOMARC Guidance*, D. W. Ladd and E. W. Wolf, Lincoln Lab., Mass. Inst. Tech.

*Liquid Transfer and Storage System Simulation by Active Element Computers*, R. D. Miller and R. K. Engel, Convair.

### Thursday Afternoon

*Chairman:* R. B. Blanning, Temco Aircraft Corp.

*Z-Forms, and the Digital Simulation of Dynamics*, V. Azgapetian, Servomechanisms, Inc.

*Some Aircraft Problems Simulated by Means of Z-Forms*, R. Boxer, Servomechanisms, Inc.

*A New Technique in System Performance Evaluation*, W. J. Nemerever, Boeing Airplane Co.

*Linear Approximation by Differential Analyzer Simulation of Orthonormal Approximating Functions*, E. G. Gilbert, Univ. of Mich.

*Solution of Convolution Integrals by Analog Computers*, F. E. Brammer, Case Inst. Tech.

### Friday Morning, October 24

*Chairman:* R. M. Howe, Aeronautical Eng. Dept., Univ. of Mich.

*Some Applications of a High-Speed Analog Correlator*, V. C. Rideout, Univ. of Wis.

*A Time-Multiplexing Technique*, E. Rawdin, RCA.

*A Method for Helicopter Rotor Performance Simulation*, W. G. Heffron and T. R. Bristow, Melpar, Inc.

*A Perturbation Technique for Analog Computers*, L. R. Bush and P. J. Orlando, Cornell Aeronautical Lab., Inc.

*Standard Simulation Circuits*, H. L. Ehlers, Autonetics Div., North American Aviation, Inc.

### Friday Afternoon

*Chairman:* C. T. Hackler, Bell Helicopter Corp.

*The Design of Position and Velocity Servos for Multiplying and Function Generation*, E. O. Gilbert, Univ. of Mich.

*The Card Programmed Diode Function Generator*, R. A. Sinker, Electrol, Inc.

*Multiplier Circuits Utilizing Squaring Property of a Triangular Wave*, D. W. C. Shen, Univ. of Pennsylvania.

*A Four Quadrant Multiplier Using Triangular Waves, Diodes, Resistors, and Operational Amplifiers*, P. E. Pfeiffer, Rice Institute.

*General Purpose DC Analog Computer with Transistor Circuitry*, H. L. Ehlers, Autonetics Div., North American Aviation, Inc.

### Saturday Morning, October 25

*Chairman:* H. D. Schwetman, Physics Dept., Baylor Univ.

*Simulation to Obtain a Systems Measure of an Air-Duel Environment*, A. B. Pritsker, R. C. van Buskirk, and J. K. Wetherbee, Battelle Memorial Inst.

*Extending the Bandwidth of Precision Analog Systems*, E. M. Billinghurst and C. H. Single, Beckman, Berkeley Div.

*Generalized Integration of the Analog Computer*, G. A. Bekey and W. H. Whittier, Ramo-Wooldridge Corp. and Beckman Computer Center.

*Transistorized Relay Amplifier*, R. Bruns and J. Wilcher, Jet Propulsion Lab., Calif. Inst. Tech.

*Airborne Radar-Beacon Traffic Simulator*, S. J. Neshyba and R. R. Coffman, Convair.

### Saturday Afternoon

*Chairman:* W. C. Duesterhoeft, Elec. Eng. Dept., Univ. of Tex.

*Optimization by Random Search on the Analog Computer*, J. K. Munson and A. I. Rubin, E. I. du Pont de Nemours & Co., and Electronic Associates, Inc.

*Computer Systems for Jet Transport Simulators*, E. G. Schwarm, Link Aviation, Inc.

*APPR-1 Simulator Description*, E. L. Morrison, Jr., RCA Service Co.

*A Technique for Absolute Measurement of Analog Computer Capacitors*, W. C. Meilander and B. H. Hellman, Goodyear Aircraft Corp.

*A Comparison of Techniques for Simulating the Flow of Discrete Objects*, D. L. Gerlough, Inst. of Transportation and Traffic Eng., UCLA.

# Thirtieth Radio Fall Meeting

OCTOBER 27–29, SHERATON HOTEL, ROCHESTER, N. Y.

### Monday Morning, October 27

#### Engineering Management

*Chairman:* D. W. Pugsley.

*A Project Team in a Functional Organization*, F. J. Bias, General Electric Co.

*The Skills of Functional Management*, C. R. Miner, General Electric Co.

#### EIA Engineering Department

*Component Parts Panel Reorganization*, L. Podolsky, Sprague Electric Co.

*Let's Speak English—Standards or Specifications*, M. A. Acheson, Sylvania Electric Products, Inc.

### Monday Afternoon

#### Quality Improvement and Reliability

*Chairman:* J. R. Steen.

*The Reliability of Television Receivers*, J. A. Cafaro, RCA.

*The Nature of Quality Control*, L. Bass, General Electric Co.

*Purchasing Reliability*, E. J. Breiding, IBM Corp.

*Over-All Quality Control in a Small TV Plant*, R. E. Gates, Sylvania Electric, Ltd. (Canada).

### Tuesday Morning, October 28

#### Radio and Television (Broadcast Receivers)

*Chairman:* J. M. Phillips.

*A New Transistor AGC Circuit*, R. L. Miller and F. J. Banovic, General Electric Co.

*Design Problems in Reflexed Transistor Receiver Circuits*, J. Waring, Philco Res. Div.

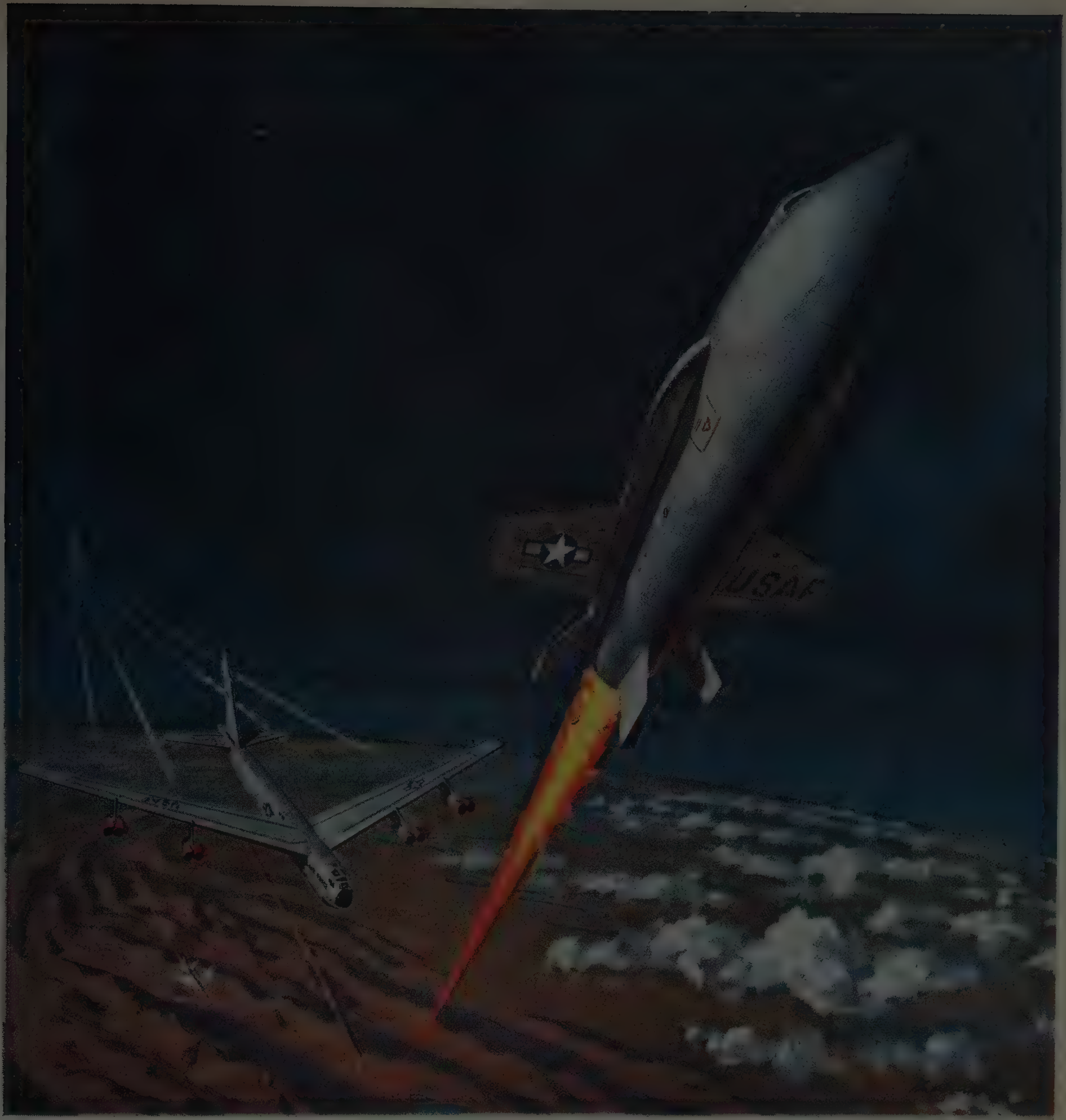
*A Sliding Class "A" Audio Output System*, J. A. Worcester, General Electric Co.

*Application of RCA Drift Transistors to FM Receivers*, J. W. Englund and H. Thanos, RCA.

*Performance Characteristics of FM Stereo Systems*, M. Crosby, Crosby Labs.

### Tuesday Afternoon

#### Radio and Television (TV Receivers)



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*Chairman:* G. A. Schupp.

*Television Receiver Color Decoder Design*, D. Richman, Hazeltine Res. Corp.

*Television IF Selectivity and Adjacent Channel Interference*, T. Matzek, Zenith Radio Corp.

*Novel Tuner For TV Receivers in the Frequency Range 500–800 MHs*, W. T. Runge, Telefunken.

*The Delta Sound System for Television Receivers*, R. B. Dome, General Electric Co.

*Wireless Remote Control*, R. Muniz, Magnavox Co.

### Tuesday Evening

### Radio Fall Meeting Dinner

*Honorary Toastmaster:* W. R. G. Baker.

*Toastmaster:* D. G. Fink, President, IRE.

*Municipal Greetings:* Hon. Peter Barry, Mayor, City of Rochester.

*Engineering Maturity*, Banquet Address, D. R. Hull, President, EIA.

### Wednesday Morning, October 29

### Electron Devices (Tubes)

*Chairman:* A. J. Heitner.

*New Techniques for Measuring VHF Loading of Miniature Tubes*, F. Sespico and W. Troyanoski, RCA.

*A Comparison of Domestic and Foreign RF Amplifier Tubes for UHF-TV*, C. Metelmann, General Electric Co.

*Low-Voltage Receiving Tubes*, T. M. Cunningham, RCA.

*A New Approach to Short Picture Tube Design*, G. A. Burdick, Sylvania Electric Products, Inc.

### Wednesday Afternoon

### Electron Devices (Transistors)

*Chairman:* R. Adler.

*Transistorized TV Horizontal Deflection and High Voltage System*, G. Schiess and W. Palmer, Sylvania Electric Products, Inc.

*Transistor Vertical Sweep Circuit*, J. G. Isabeau, Zenith Radio Corp.

*Transistorized Entertainment Type FM Receivers*, H. F. Cooke, Texas Instruments, Inc.

*A Low-Cost High-Gain TV IF Transistor—Its Application and Characteristics*, C. D. Simmons, Lansdale Tube Co.

# Fifth Annual East Coast Conference on Aeronautical and Navigational Electronics

October 27–28, Lord Baltimore Hotel, Baltimore, Md.

The East Coast Conference on Aeronautical and Navigational Electronics will be held in the Lord Baltimore Hotel, Baltimore, Md., on October 27–28. The problems of air safety, and development of an effective system of air traffic control, will be the major topics of discussion. New techniques in air navigation, and new systems for air traffic control and radar will be described in a program of over thirty technical papers. There will also be an electronics show including exhibits of navigational systems, test equipment, and their components.

The Conference is sponsored by the Baltimore Section and the PGANE. For further information, please contact H. S. Karstein, Eastern Associates, Inc., 5612 Belleville Avenue, Baltimore 7, Md.

### Monday Morning, October 27

### Air Traffic Control

*Chairman:* J. General, Deputy Commander for Research and Development, ARDC.

*Evaluation of VOR on a 200-Foot Tower*, R. B. Flint, CAA.

*AN/FPN-34 Air Traffic Control Radar*, K. F. Molz, Bendix Radio.

*Operation of ASDE at Idlewild*, J. E. Woodward, Airborne Instruments Lab.

*An All-Channel, Transistorized, Glide Slope Receiver*, E. B. Moore and T. F. Houghton, Aircraft Radio Corp.

*An All-Transistor, Three Light Marker-Beacon Receiver*, A. L. Cleland and E. B. Moore, Aircraft Radio Corp.

*A Mobile Tacan Beacon: Its Description and Uses*, A. Casabona, Federal Telecommun. Lab.

### Aircraft Instrumentation, Studies, and Techniques

*Chairman:* D. D. King, Vice-President, Res. Div., Electronic Communications, Inc.

*Conical Scan Tracking in Ground Clutter with Non-Coherent and Coherent MTI*, C. Sorkin, General Atronics Corp.

*A Rapid Wide-Angle Scanning Antenna with Minimum Beam Distortion*, R. W. Martin and L. Schwartzman, Sperry Gyroscope Co.

*An Electrically Scanned Spiral Antenna*, M. S. Wheeler, Westinghouse Air Arm.

*Silicon Diode Applications in Radar Set AN/FPN-34*, A. E. Hammel, Bendix Radio.

*A Null Balancing Microwave Hygrometer for Airborne Use*, M. S. Morse, Natl. Bur. of Standards.

*An Integrated Airborne System for Field Intensity Measurements*, S. R. Jones and T. W. Tunney, Melpar, Inc., and L. R. Wever, Air Force Missile Test Center, Patrick AFB.

### Monday Afternoon

### Test and Evaluation

*Chairman:* S. N. Friedman, Westinghouse Electric Corp.

*The Electrical Compass Swinging System*, M. Skaar and M. Depp, Sperry Gyroscope Co.

*The AN/USQ-11 Miss Distance Measuring System*, P. Yaffee, Naval Ordnance Lab.

*Radio Interference Testing of a Completed Aircraft*, E. H. Heineman, Douglas Aircraft Co., Inc.

*Reliability Analysis of AN/FPN-81 System in a Field Operation*, D. Harder and J. Strell, General Precision Lab.

*Airborne Tacan Test Equipment*, W. Robinson, Federal Telecommun. Lab.

*Propagation Aspects of an Integrated Airborne System for Field Intensity Measurements*, A. P. Murphy and P. L. Bachman, Melpar, Inc.

### Navigational Techniques

*Chairman:* R. W. Wells, Chief Electronics Engineer, Aircraft Armaments, Inc.

*A System of Coordinates for Space*, C. M. Jones, AFCRC.

*Coordinate Systems for Navigation and Air Traffic Control*, H. K. Morgan, Bendix Aviation Corp.

*Inertial Navigation in Hypersonic Aircraft*, F. F. Daigle, RCA Aviation Systems Lab.

*Some Aspects of the Properties of the Gravitation Field and Its Possible Applications to Space Navigation*, J. C. Crowley, S. S. Kolodkin, and A. M. Schneider, RCA Airborne Systems Lab.

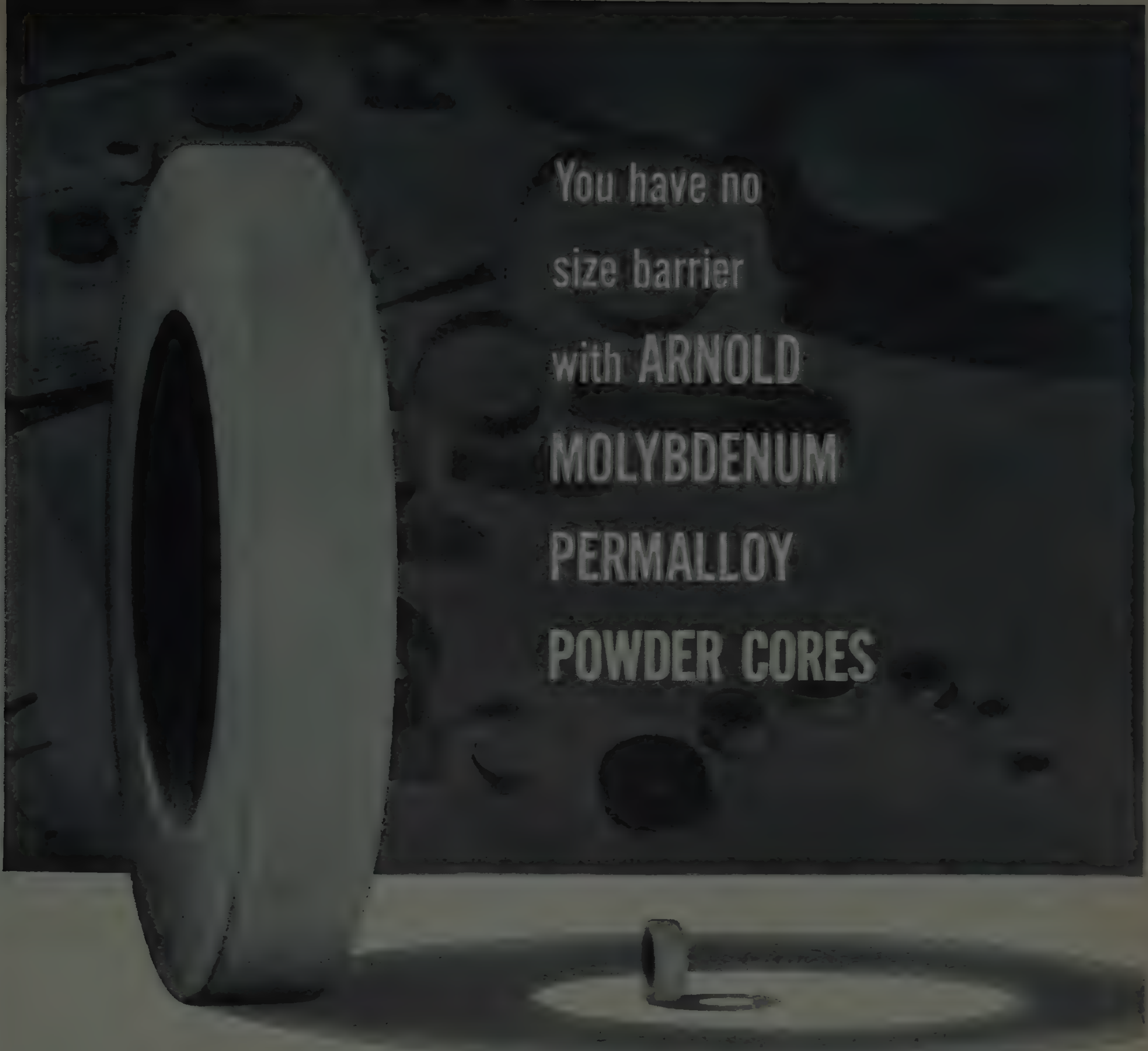
*The Canadian Lightweight Doppler Navigation Radar*, R. K. Brown, Defence Res. Telecommun. Establishment, Defence Res. Board, Ottawa, Can.

### Tuesday Morning, October 28

### Computer Techniques

*Chairman:* C. W. Barbour, Jr., Vice-President, Engineering, Hoover Electronics Co.

*An Error Analysis of an Airborne Electro-Mechanical Analog Computer*, B. S. Holland, Mergenthaler Linotype Co.



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*General Purpose DC Analog Computer with Transistor Circuitry*, H. L. Ehlers, Autonetics.

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*High Performance Aircraft Flareout*, A. Tatz and F. H. Battle, Jr., Airborne Instruments Lab.

*Computers for Inertial Navigation*, H. R. Brown, Autonetics.

*Pulsed Radar Receiver Simulation by Electronic Analog*, S. Barda, R. D. Bidne, and T. A. Priscilla, Westinghouse Air Arm.

### Equipment Design Criteria

*Chairman:* G. J. Strickroth, Glenn L. Martin Co.

*Analysis and Correction of Vibration Failures of Rigid Mounted Airborne Electronic Equipment*, J. G. Kuller, W. S. Harkness, and J. A. Lake, Bendix Radio.

*Cumulative Probability of Detection for a Fluctuating Target*, J. Dukas, Westinghouse Air Arm.

*Water Cooling Versus Air Cooling in Airborne Electrical Equipment*, J. Kovalsky, Federal Telecommun. Lab.

*A Transistorized High Duty Factor PPI Sweep Circuit*, C. E. Venzie, Glenn L. Martin Co.

*Derivation and Analysis of a Track-While-Scan System*, B. S. Rudman, Sperry Gyroscope Co.

*On the Application of Fourier Orthogonal Filters*, H. Blasbalg, Electronic Communications, Inc.

### Tuesday Afternoon

### Air Traffic Control

*Chairman:* D. M. Stuart, Director, Technical Dev. and Evaluation Ctr., CAA.

*Simulation Studies of Air Traffic Control Problems in High Density Areas*, T. K. Vickers, CAA, and R. S. Miller, Franklin Inst.

*An Electronic Air Traffic Control Simulator*, W. H. Rhodes and W. H. Gable, Aircraft Armaments, Inc.

*The Data Processing and Display Technical Program I*, R. A. Finkler and N. Pomerance, General Precision Lab.

*The Data Processing and Display Technical Program II*, N. Pomerance and R. A. Finkler, General Precision Lab.

*The Directional Localizer*, S. E. Taggart and O. J. DeZoute, CAA.

### Aircraft Instrumentation, Studies, and Techniques

*Chairman:* C. I. Rice, Aviation Products, Bendix Radio.

*A 10-Watt Transistor Servo Amplifier*, J. Grabowski, Minneapolis-Honeywell Regulator Co.

*Airborne Electronic Weather Observing System*, J. R. Cosby, Bendix Friez.

*Design Concepts of a High Brightness Radar Indicator*, E. W. Koenig, Farnsworth Electric Co.

*A Video Amplifier with a 30 MC Bandwidth*, W. A. Zins, Glenn L. Martin Co.

*Pulsed Modulator Silicon Clipper*, M. G. Gray, Westinghouse Air Arm.

*An Automatic Doppler Cycle Counter*, B. E. Keiser, Missouri Research Labs., Inc.

# Fifth Annual Meeting of the Professional Group on Nuclear Science

NOVEMBER 6–7, VILLA MOTEL, SAN MATEO, CALIF.

### Thursday Morning, November 6

### Electronics for Particle Accelerators

*A Chronotron for Relativistic Neutron Time of Flight Measurements*, R. H. Ragsdale and W. F. Stubbins, Radiation Lab., Univ. of Calif.

*Beam Profile Indicator*, H. G. Jackson, D. A. Mack, and C. Wiegand, Radiation Lab., Univ. of Calif.

*Nanosecond Pulse Transformers*, C. N. Winningstad, Radiation Lab. Univ. of Calif.

*Scatterbrain—An Automated Experiment on the Ninety Inch Cyclotron*, J. Benveniste, E. A. LaFranchi, G. E. Strahl, and R. L. Swenson, Radiation Lab., Univ. of Calif.

### Thursday Afternoon

### Electronics for Controlled Fusion Research

*Electronic Systems Used for Controlled Fusion Research*, V. L. Smith, Radiation Lab., Univ. of Calif.

*Report on the Geneva Conference; Developments in Controlled Fusion Electronics*, H. W. VanNess, Radiation Lab., Univ. of Calif.

*Development of Switching Components for Controlled Fusion Research*, D. B. Cummings, Radiation Lab., Univ. of Calif.

*Microwave Interferometer Measurements for the Determination of Density Profiles in Controlled Fusion Experiments*, C. B. harton and D. M. Slager, Radiation Lab., Univ. of Calif.

### Friday Morning, November 7

### Reactor Instrumentation

*Instrumentation and Control System for the Westinghouse Testing Reactor*, L. F. Kardos, Westinghouse.

*Servo Logarithmic Amplifier for Reactor Instrumentation*, W. J. Hartin, Bendix.

*Design of a Power-Limiting System for a Sodium Cooled Atomic Power Plant*, E. H. Lemon and J. Talboy, Bendix.

*Transistorized Reactor Instrumentation and Protective Circuits*, D. J. Niehaus and R. R. Hogg, Bendix.

*Transistorized Log-Period Amplifier*, E. J. Wade and D. S. Davidson, General Electric Co.

### Friday Afternoon

### Nuclear Radiation—Effects, Detection, and Measurements

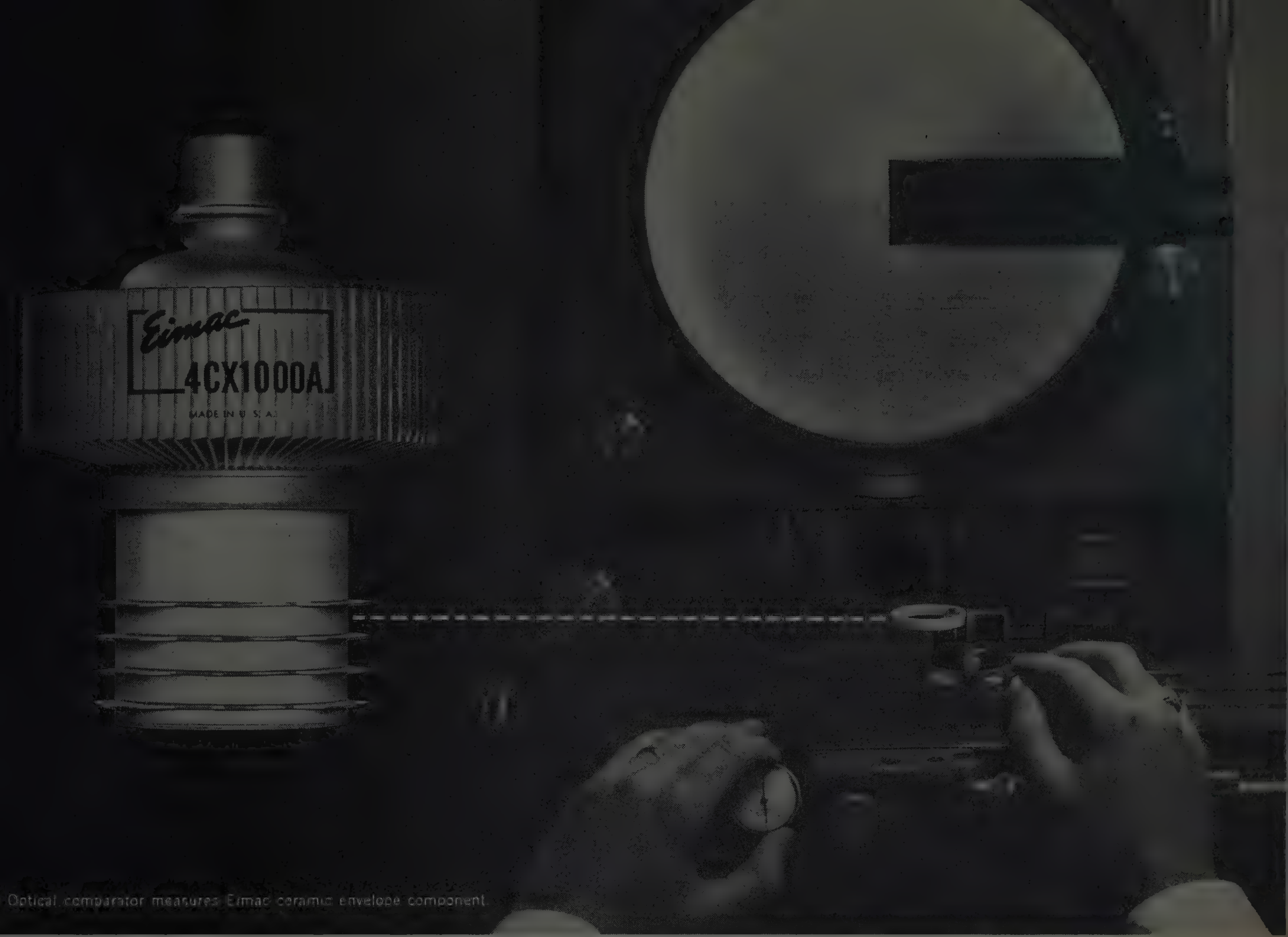
*Some Beneficial Effects of Nuclear Radiation on Electron Devices*, J. R. Hendrickson, RCA.

*Transistorized Linear Pulse Amplifier*, S. Baker, Radiation Lab., Univ. of Calif.

*Transistorized Beam Switching Tube Printout Scaler*, R. H. Graham, Radiation Lab., Univ. of Calif.

*Automatic Recording and Processing of Radioactive Decay Data*, J. Howland, R. Kaifer, E. LaFranchi, G. Nelson, R. Payne, and R. Swenson, Radiation Lab., Univ. of Calif.

* * *



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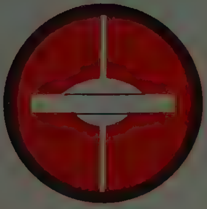
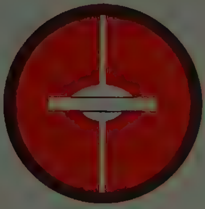
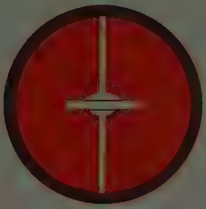


**40 Watts***



**30 Watts***



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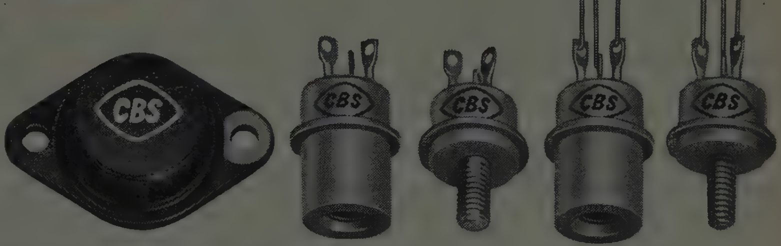

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### 40-WATT GROUP

Types Available

| Current Gain‡ | 30V | 60V | 80V | 100V | Packages# |
|---|---|---|---|---|---|
| 160 | LT-5096 | LT-5105 | LT-5114 | LT-5123 | Diamond |
| | LT-5095 | LT-5104 | LT-5113 | LT-5122 | Male |
| | LT-5094 | LT-5103 | LT-5112 | LT-5121 | Female |
| 80 | LT-5093 | LT-5102 | LT-5111 | LT-5120 | Diamond |
| | LT-5092 | LT-5101 | LT-5110 | LT-5119 | Male |
| | LT-5091 | LT-5100 | LT-5109 | LT-5118 | Female |
| 40 | LT-5090 | LT-5099 | LT-5108 | LT-5117 | Diamond |
| | LT-5089 | LT-5098 | LT-5107 | LT-5116 | Male |
| | LT-5088 | LT-5097 | LT-5106 | LT-5115 | Female |

Minimum Breakdown Voltage†

### 30-WATT GROUP

Types Available

| Current Gain‡ | 30V | 60V | 80V | 100V | Packages# |
|---|---|---|---|---|---|
| 100 | LT-5060 | LT-5069 | LT-5078 | LT-5087 | Diamond |
| | LT-5059 | LT-5068 | LT-5077 | LT-5086 | Male |
| | LT-5058 | LT-5067 | LT-5076 | LT-5085 | Female |
| 60 | LT-5057 | LT-5066 | LT-5075 | LT-5084 | Diamond |
| | LT-5056 | LT-5065 | LT-5074 | LT-5083 | Male |
| | LT-5055 | LT-5064 | LT-5073 | LT-5082 | Female |
| 30 | LT-5054 | LT-5063 | LT-5072 | LT-5081 | Diamond |
| | LT-5053 | LT-5062 | LT-5071 | LT-5080 | Male |
| | LT-5052 | LT-5061 | LT-5070 | LT-5079 | Female |

Minimum Breakdown Voltage†

### 20-WATT GROUP

Types Available

| Current Gain‡ | 30V | 60V | 100V | **120V** | Packages# |
|---|---|---|---|---|---|
| 60 | LT-5028 | LT-5034 | LT-5042 | LT-5051 | Diamond |
| | LT-5027 | LT-5033 | LT-5041 | LT-5050 | Male |
| | LT-5026 | LT-5032 | LT-5040 | LT-5049 | Female |
| 40 | LT-5025 | LT-5031 | LT-5039 | LT-5048 | Diamond |
| | LT-5024 | LT-5030 | LT-5038 | LT-5047 | Male |
| | LT-5023 | LT-5029 | LT-5037 | LT-5046 | Female |
| 20 | LT-5022 | 2N157 | 2N157A | LT-5045 | Diamond |
| | LT-5021 | LT-55 | LT-5036 | LT-5044 | Male |
| | 2N156 | 2N158 | LT-5035 | LT-5043 | Female |

Minimum Breakdown Voltage†

‡Minimum large-signal current gain: 40-watt group at 1.0 A, 30-watt group at 0.75 A, 20-watt group at 0.50 A.

†Minimum breakdown voltage, collector to base with emitter open.

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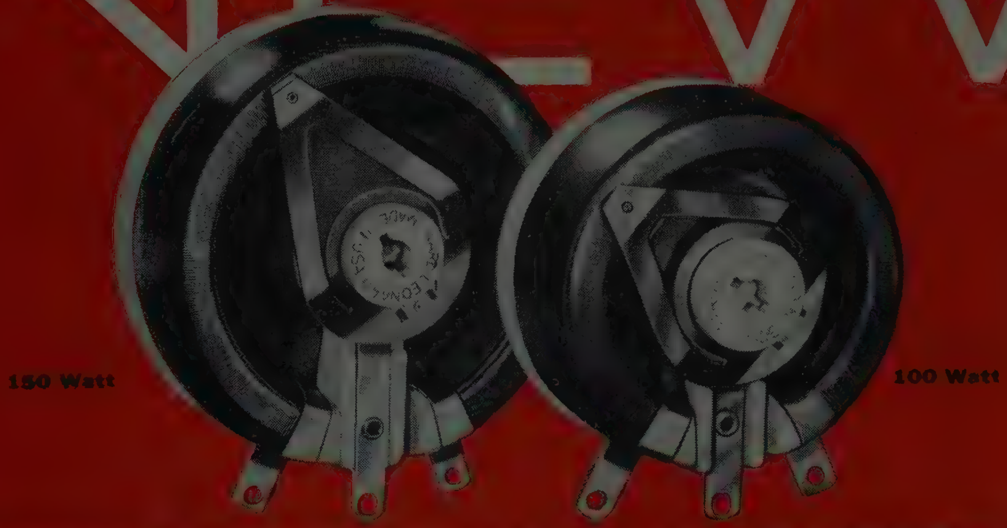

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J. F. Chappell
V. Mancino

### 27.2 DEFINITIONS

### 27.3 RADIO AND TV RECEIVERS

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E. W. Chapin
M. S. Corrington
E. C. Freeland
R. O. Gray
W. R. Koch
S. Mazur
W. G. Peterson
D. G. Thomas
F. R. Wellner
A. E. Wolfram
R. S. Yoder

### 27.4 RADIO TRANSMITTERS

W. F. Goetter, *Chairman*

H. R. Butler
W. F. Byers
V. Mancino
J. F. Proper
H. S. Walker

### 27.5 INDUSTRIAL ELECTRONICS

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### 27.12 Navigational and Communication Equipment

## 17. Radio Receivers

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K. Farr
W. R. Koch
R. N. Rhodes
D. Richman
L. Riebman

### 17.11 AM-FM Broadcast Receivers

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E. Cornet
R. J. Farber
J. Merklenger

## 15. Radio Transmitters

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J. B. Singel, *Vice-Chairman*

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H. R. Butler
C. G. Dietsch
W. R. Donsbach
H. Goldberg
H. E. Goldstine
R. N. Harmon
J. B. Heffelfinger
P. J. Herbst
L. A. Looney
S. M. Morrison
J. Ruston
B. Sheffield
B. D. Smith
I. R. Weir
V. Ziemelis

### 15.1 FM Transmitters

J. Ruston, *Chairman*

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J. R. Boykin
N. Marchand
P. Osborne
H. P. Thomas

### 15.2 Radio-Telegraph Transmitters up to 50 MC

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C. J. Dietsch
B. Sheffield

### 15.3 Double Sideband AM Transmitters

J. B. Heffelfinger, *Chairman*

W. T. Bishop, Jr.
D. H. Hax
E. J. Martin, Jr.

### 15.4 Pulse-Modulated Transmitters

B. D. Smith, *Chairman*

R. Bateman
L. V. Blake
L. L. Bonham
H. Goldberg
G. F. Montgomery
W. K. Roberts

### 15.5 Single-Sideband Radio Communication Transmitters

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H. E. Goldstine
A. E. Kerwien
E. A. Laport

### 15.6 Television Broadcast Transmitters

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E. Hamilton
R. Jose
L. A. Looney
J. Ruston
J. L. Stern
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## 19. Recording and Reproducing

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M. Camras
W. R. Chynoweth
F. A. Comerci
E. W. D'Arcy
A. W. Friend
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L. Thompson
T. G. Veal
B. J. White

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T. Dewey
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O. Kornei
K. I. Lichti
E. G. Newman
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L. Thompson
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### 19.3 Optical Recording

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J. A. Maurer
E. Miller
C. Townsend

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G. L. Davies
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D. Dubbe
U. R. Furst
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## 28. Solid-State Devices

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W. M. Webster, *Vice-Chairman*
V. P. Mathis, *Secretary*

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A. W. Lampe
E. E. Loebner
L. T. MacGill
R. H. Rediker
R. W. Rochelle
J. R. Roeder
B. J. Rothlein
J. Saby
S. Sherr
C. F. Spitzer

### 28.4 Semiconductor Devices

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A. C. Sheckler, *Chairman (AIEE)*

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R. L. Bright
E. N. Clarke
A. Coblenz
S. K. Ghandhi
J. M. Hall
B. Jacobs
J. D. Johnson
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R. M. LeLacheur
B. R. Lester
R. P. Lyon
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C. W. Mueller
M. B. Prince
R. L. Pritchard
B. J. Rothlein
H. N. Sachar
A. P. Stern
R. L. Trent
R. Ure

### 28.4.2 Methods of Test for Transistors for Linear CW Transmission Service

A. Coblenz, *Chairman*

### 28.4.3 Definitions and Letter Symbols of Semiconductors

B. J. Rothlein, *Chairman*

### 28.4.4 Methods of Test for Semiconductor Devices for Large-Signal Applications

R. L. Trent, *Chairman*

A. W. Berger
F. H. Blecher
R. S. Hill
C. Huang
R. M. LeLacheur

### 28.4.5 Methods of Test for Bulk Semiconductors

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D. C. Cronemeyer
I. Drukaroff
J. R. Haynes
A. Kestenbaum
M. F. Lamorte
J. Mandelkorn
B. J. Rothlein
D. T. Stevenson
K. W. Uhler

### 28.4.6 Photo Devices

M. B. Prince, *Chairman*

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M. Adelman
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R. Christensen
J. Defandorf
G. Dermit
I. A. Lesk
D. E. Sawyer

### 28.4.7 Transistor Internal Parameters

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W. M. Webster

### 28.4.8 Semiconductor Devices Symbols Task Group

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### 28.4.9 Semiconductor Diode Definitions

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D. C. Dickson
B. Jacobs
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### 28.4.10 Semiconductor Diode Measurements

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C. Irwin
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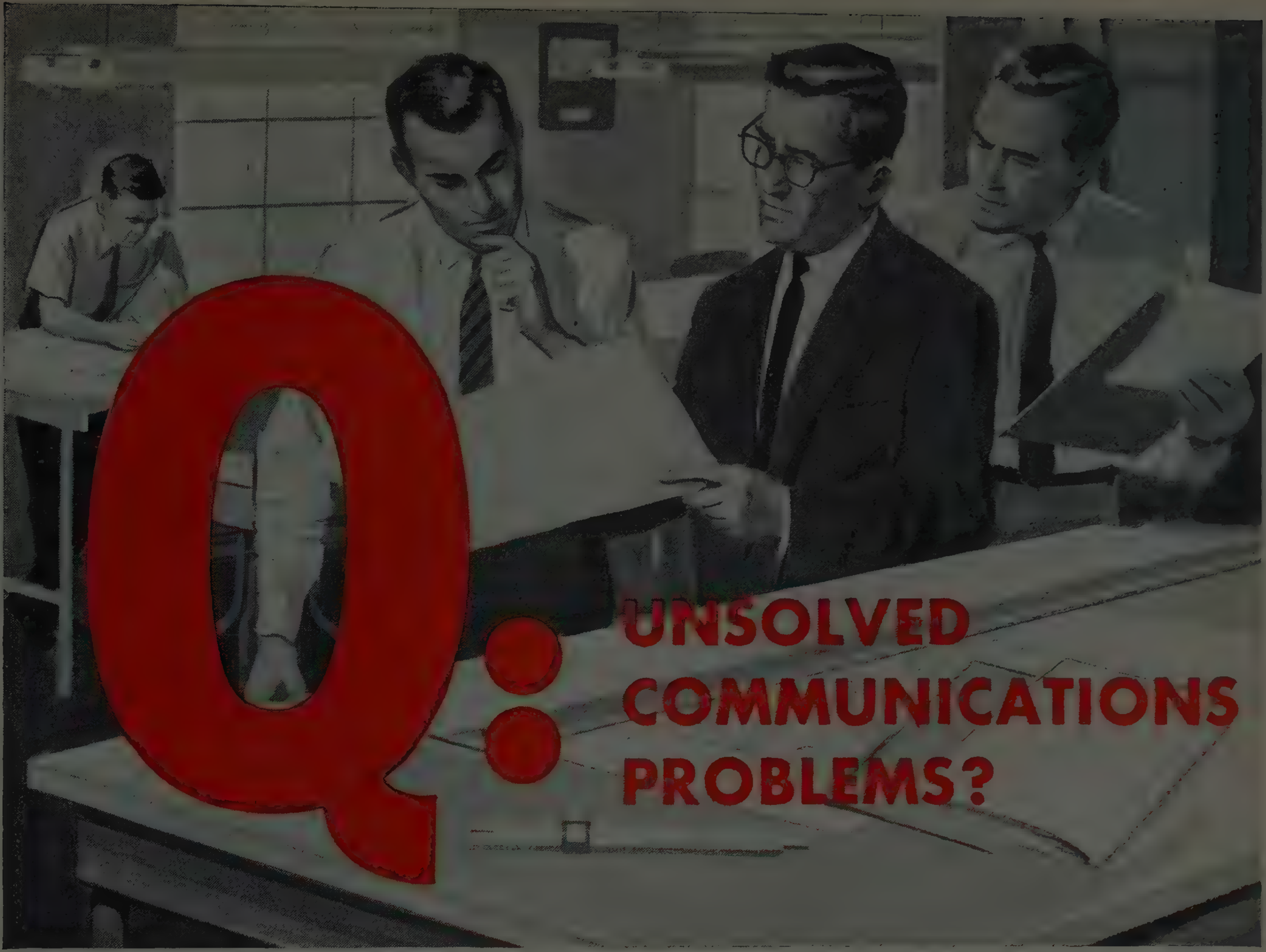

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### 28.5 Dielectric Devices

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H. I. Oshry
C. F. Pulvari
N. Rudnick
E. A. Sack
E. Schwenzfeger
F. A. Schwertz
B. R. Shepard
C. F. Spitzer
L. E. Walkup

### 28.5.1 Nonlinear Capacitor Definitions

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W. Gardner
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H. L. Ivey
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F. A. Schwertz
C. F. Spitzer

### 28.5.3 Definitions, Formation and Utilization of Electrostatic Images

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### 28.6 Magnetic Devices

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### 21.3 Functional Symbols for Switching and Control Equipment

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### 21.5 New Proposals and Special Assignments

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### 22.2 Television Picture Element

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T. V. Zalovdek

## 23. Video Techniques

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### 23.1 Definitions

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F. Herr

### 23.3 Video Systems and Components Methods of Measurement

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J. R. Hefele
A. Lind
N. E. Sprecher
E. Stein
W. B. Whalley

### 23.4 Video Signal Transmission Methods of Measurement

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O. G. Villard, Jr.
J. P. Voge
J. R. Wait
A. T. Waterman
A. H. Waynick

### 24.1 Standards and Practices

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### 24.2 Tropospheric Propagation

T. J. Carroll, *Chairman*

### 24.3 Ionospheric Propagation

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# VISUAL MICROWAVE ANALYSIS—10 to 44,000 mc

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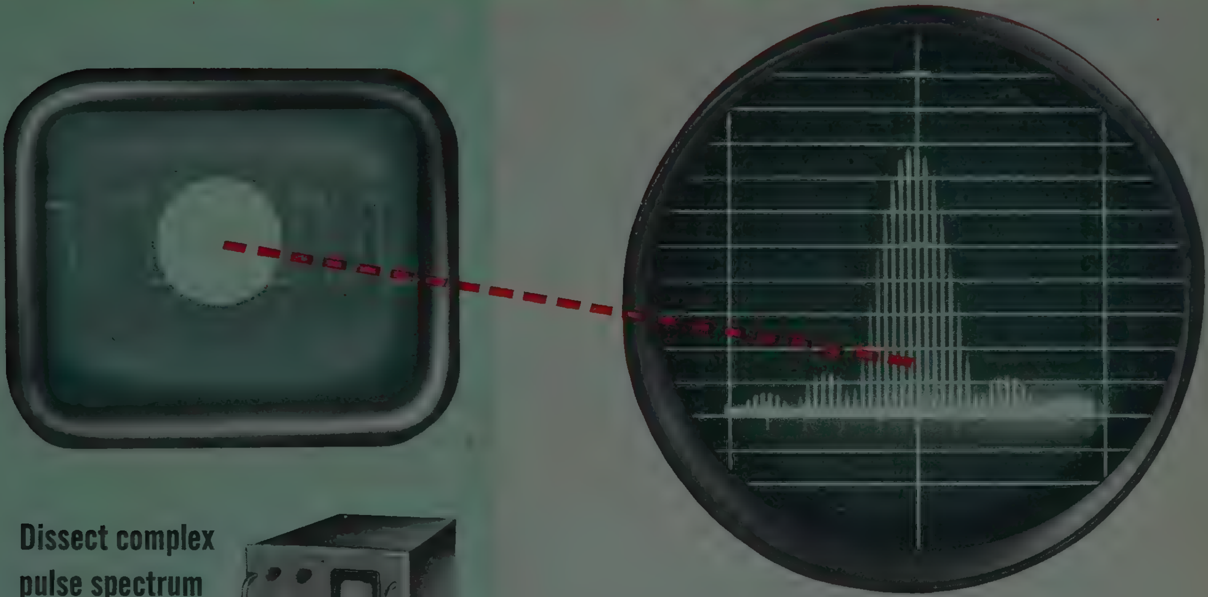


Dissect complex pulse spectrum visually by means of Polarad Model SD-1

## MULTI-PULSE SPECTRUM SELECTOR

Used with any Polarad analyzer, this Model SD-1 Spectrum Selector permits complete analysis of any complex pulse modulated microwave signals. The unit decodes and isolates any segment of a complex pulse train and permits corresponding spectrum analysis of that segment.

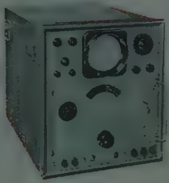
Model SD-1 Spectrum Selector displays pulse groups up to 180 microseconds duration (Model SD-1X: 350 microseconds).

**Applications:**

Design and operation of radar, telemetry equipment, IFF systems and beacons.

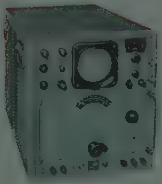
Analyze complex spectrum visually using any of Polarad's wide band

## MICROWAVE ANALYZERS



**Model TSA Spectrum Analyzer** —25 kc resolution, 400 kc to 25 mc dispersion. 5 sensitive plug-in tuning units.

**Model TSA-S Combination Synchroscope-Spectrum Analyzer** —Displays pulse waveform or frequency spectrum. 5 kc to 5 mc adjustable bandwidth, 400 kc to 25 mc dispersion. 5 sensitive plug-in tuning units.



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**Performs** general purpose signal generator and oscilloscope measurements, multi-pulse testing and analysis.

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**Frequency range 950 to 10,750 mc is covered by four** interchangeable microwave oscillator units, all stored in the instrument. Each has UNI-DIAL control, precision power monitor circuit to maintain 1 milliwatt power output reference level, and non-contacting short-type chokes to assure long life.

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Code modulation is achieved with five independently adjustable pulse channels providing: **pulse repetition rate variable,** 10-10,000 pps; **width variable** 0.2 to 2 **microseconds: delay variable** 0-300 **microseconds. Pulse rise and decay,** 0.1 microsecond.

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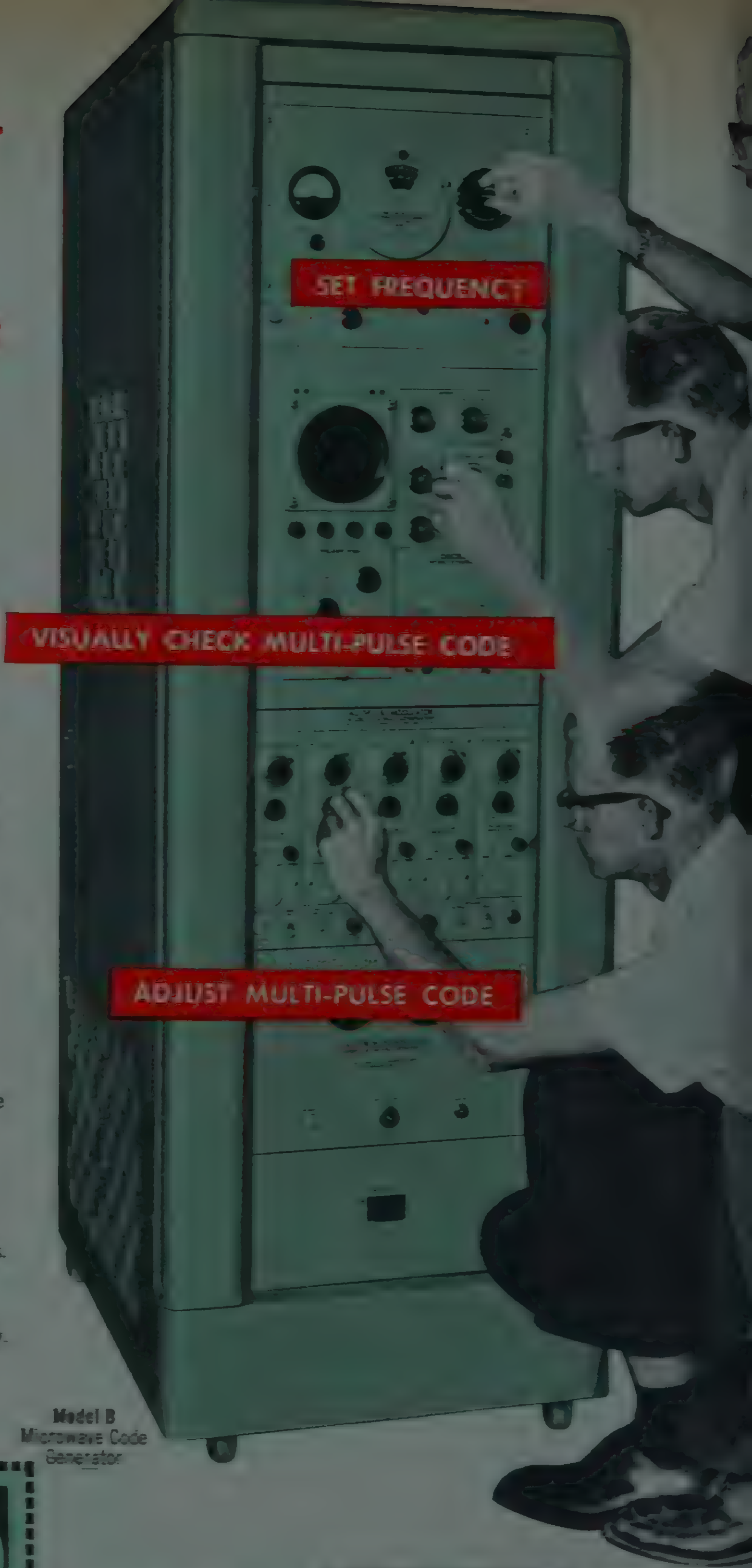

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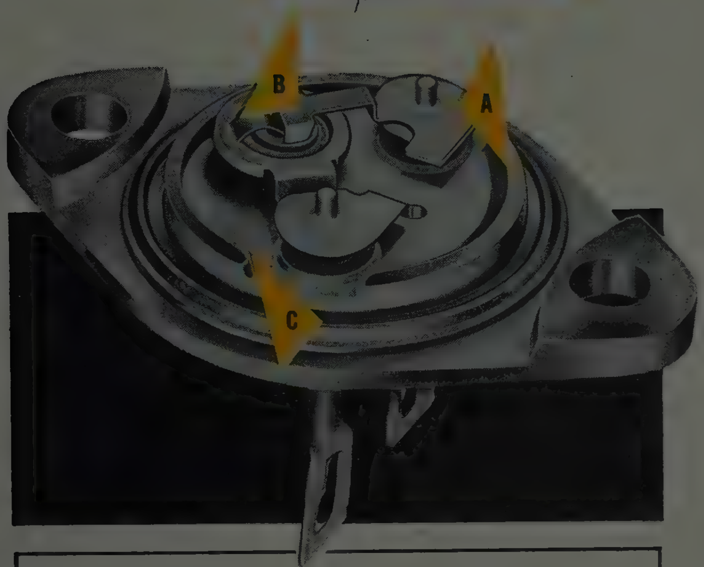
# Transistors



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**B** ● Miracle-Ring Emitter provides greater effective area permitting higher current operation.

**C** ● Industry standard TO-3 package with solder terminals and welded hermetic seal is designed to meet or exceed the mechanical and environmental requirements of military specification MIL-T-19500A.

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### GENERAL SPECIFICATIONS

| TYPE NUMBER | $BV_{CBO}$ max volts | $BV_{CES}$ max volts | $h_{FE}$ $I_C=10A$ min | max | $V_{CE\ sat}$ $I_C=10A$ $I_B=1A$ max volts |
|---|---|---|---|---|---|
| 2N627 | 40 | 30 | 10 | 30 | 1.0 |
| 2N628 | 60 | 45 | 10 | 30 | 1.0 |
| 2N629 | 80 | 60 | 10 | 30 | 1.0 |
| 2N630 | 100 | 75 | 10 | 30 | 1.0 |

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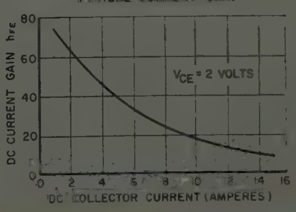

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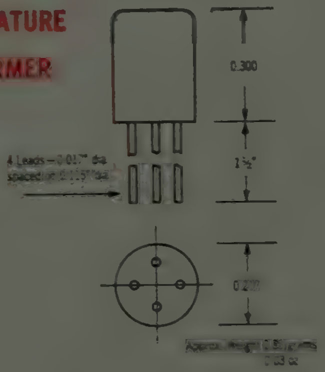

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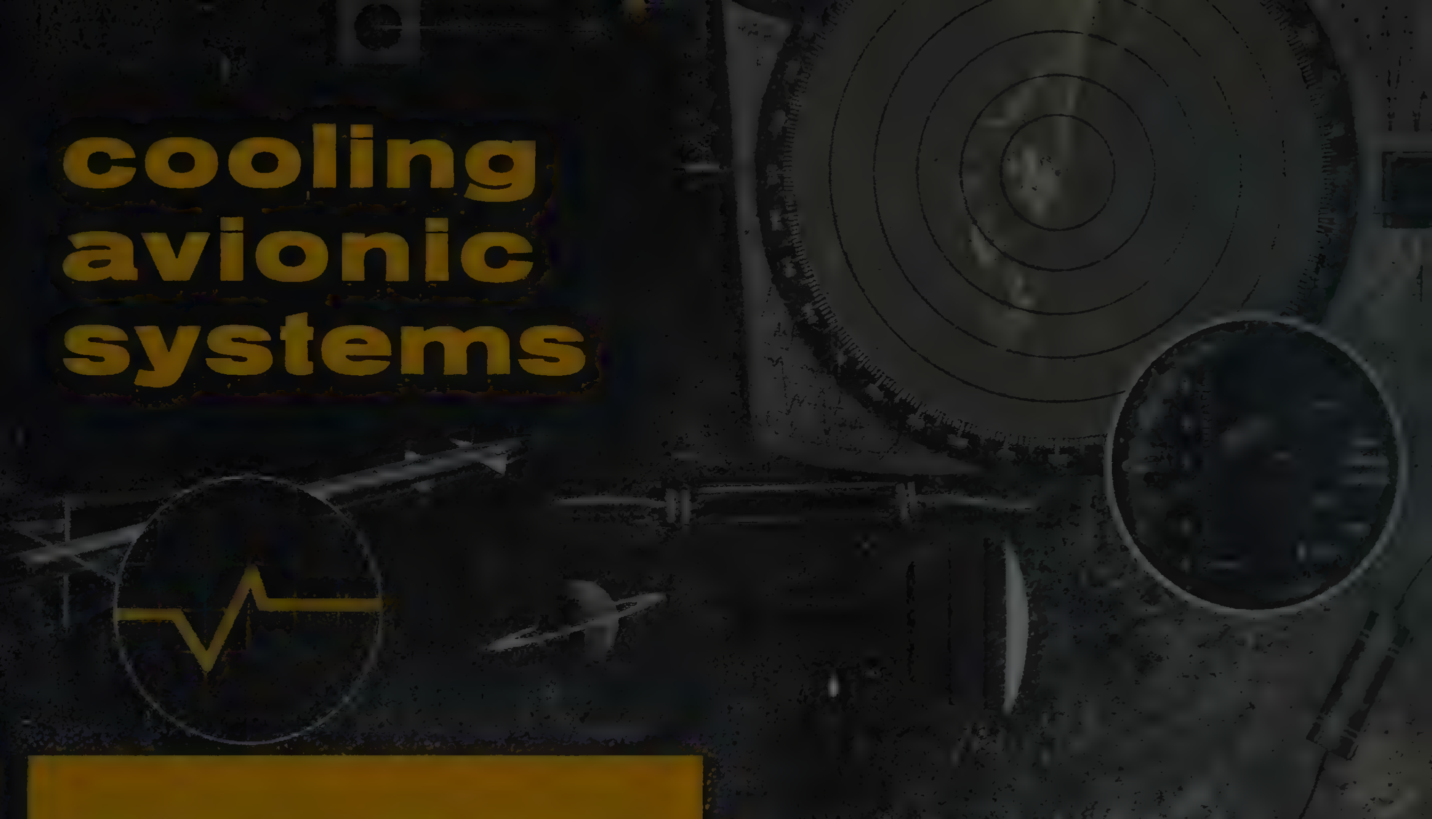
# cooling avionic systems



During World War II, Eastern Industries pioneered cooling systems for aircraft electronic systems. Now, thousands of installations later, and as the leader in this challenging field, Eastern is still pioneering.

Experience has been a springboard to new developments . . . compactness, simplification, refrigeration cycles. Research and development continue to play their vital parts in perfecting systems to overcome the new problems as expanded aircraft performance produces fantastic rises in temperatures.

If you have a challenging problem, come to the leader in the field for complete and creative engineering help.

*COOLING UNIT*

*REFRIGERATION-TYPE*

## ELECTRONIC TUBE COOLING UNITS

Custom-made units, with or without refrigeration cycles, provide a method of maintaining safe operating temperature limits in electronic equipment. Standard sub-assemblies and components normally are used to create a custom-made design to fit your exact needs. Costs are minimized for these completely self-contained units by combining heat exchangers, fans or blowers, liquid pumps, reservoirs, flow switch, thermostat, and other common components.

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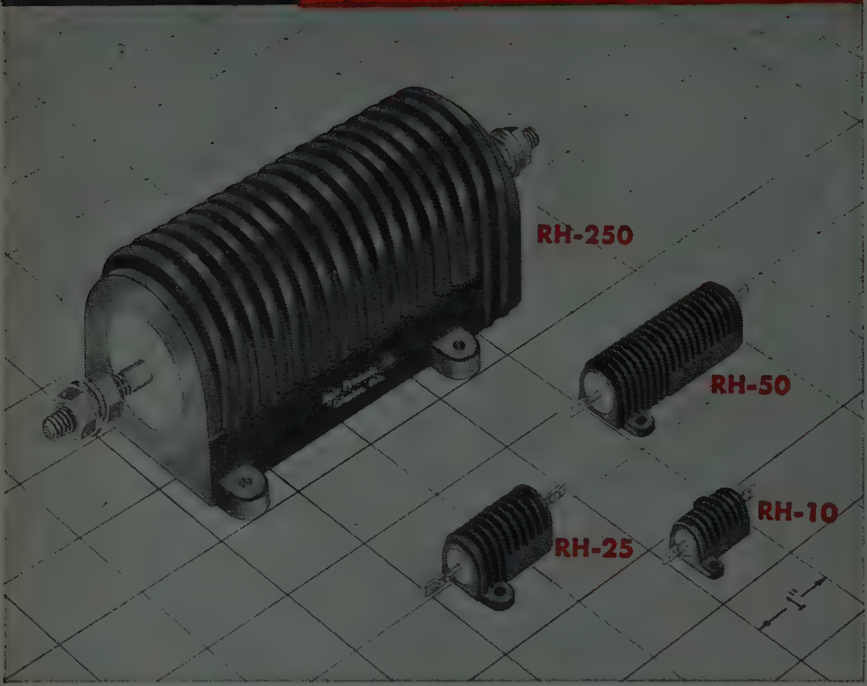
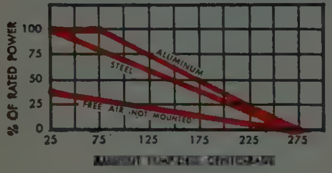
...for Complete Reliability Under Severe Environmental Conditions



TYPE RH POWER RESISTORS

Wire Wound, Precision, Miniature, Ruggedized

TYPICAL DERATING CURVE



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If none of the DALOHM standard line meets your need, our engineering department is ready to help solve your problem in the realm of development, engineering, design and production.

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Designed for the specific application of high power requirements, coupled with precision tolerance. Mounts on chassis for maximum heat dissipation. Operates under severe environmental conditions as outlined in specifications below.

- Rated at 10, 25, 50 and 250 watts.
- Resistance range from 0.1 ohm to 175K ohms, depending on type.
- Tolerance 0.05%, 0.1%, 0.25%, 0.5%, 1%, 3%.

**TEMPERATURE COEFFICIENT:** Within ±0.00002/degree C.

**COMPLETE PROTECTION:** 100% impervious to moisture and salt spray.

**WELDED CONSTRUCTION:** Complete welded construction from terminal to terminal.

**RUGGED HOUSING:** Sealed in silicone, inserted in radiator finned aluminum housing.

**MINIATURE SIZE:** 7/16 x ¾ to 3 x 4-½ inches.

**MILITARY SPECIFICATIONS:** Surpasses applicable paragraphs.

# Section Meetings

### AKRON

"Our Country's Space Program," F. H. Kierstedt, Jr., Goodyear Aircraft; 6/17/58.

### ALAMOGORDO-HOLLOMAN

Social Evening; 7/25/58.

### BUENOS AIRES

"Electronics Week," Closing Dinner; 4/18/58.

"Modern Ceramics and Their Application to Electronic Industries," J. O. Ciarrapico; 5/9/58.

"Nuclear Physics—The Present Outlook," D. W. Gamba, 5/22/58.

"Fundamentals of Micro-Wave Circuits," J. A. DelGiorgio; 6/12/58.

"Some Aspects of the Manufacture of Cathode-Ray Tubes," J. Espoueys, O. Espoueys; 6/26/58.

"Indirectly Controlled Telephone Systems," A. R. LaGarde; 7/10/58.

"Recent Developments in Automatic Radio Direction Finding Systems, from Ground, as Applied to Aviation," R. F. Cleaver; 7/15/58.

"Present Day Methods of Radio-Telegraphy using Teletypes, or Teleprinters," M. E. Valentinuzzi; 7/24/58.

### FORT WORTH

"Effects of Nuclear Radiation on Electronic Components at High Temperature," J. R. Crittenden, G. E. Co.; 4/15/58.

"A Digital A.C. Voltage Ratio Encoder," B. Falk, Convair; "Scimitar Antenna Development," D. R. Robertson, D. G. Harman, Convair; "The Use of Heater Voltage Variation to Detect Marginal Tubes," R. D. Hicks, Convair; 5/20/58.

### INDIANAPOLIS

Tour, WLW-I Transmitter Side, N. H. Nixon WLW-I TV; 4/25/58.

"An Improved High-Gain Panel Light Amplifier," B. Kazan, RCA Labs.; 5/27/58.

Tour, CAA Technical Development Center, J. Eastor, Civil Aeronautics Adm. TDC; 6/13/58.

"Closed Circuit Television As Applied to Education and Industry," J. Hofeld, Private Television Systems, Inc.; 7/25/58.

### OMAHA-LINCOLN

Panel Discussion—Professional Group Chapter Activities; 7/18/58.

### PITTSBURGH

Tour, Laboratory and Inspection of Equipment and Facilities, Gulf Research and Development Lab.; 4/14/58.

### ROME-UTICA

Social Meeting; 6/6/58.

Dinner Meeting, Short Talk, Donald G. Fink, IRE President, 6/27/58.

### SALT LAKE CITY

"The Future of the IRE," Donald G. Fink, IRE President, 4/25/58.

"The History of Litton Industries," V. D. Carver, Litton Industries; "Microwave Tubes," B. D. Kumpfer, Litton Industries; 5/27/59.

"Radio Propagation Studies of Lightning Discharges, C. Alley, Univ. of Utah; 6/19/58.

## *SUBSECTIONS*

### LAS CRUCES-WHITE SANDS

Dinner, Installation of Officers; 7/29/58.

### ORANGE BELT

"The Video Tape Recorder," F. Gonzalez, Ampex Co.; 6/17/58.

# Industrial Engineering Notes*

ENGINEERING

**Five new recommended standards for the electronics industry have been made available to industry.** The standards were published following approval by representatives of the industry, including members and non-members of EIA. EIA member-company representatives have received the standards which are available to all segments of the electronics industry. Nonmembers of the Association may obtain copies of the following standards through the EIA Engineering Department in New York City (a minimum charge of $1 is made on all orders): RS-165-A—Ceramic Dielectric Capacitors, Classes 1 & 2, 1000–7500 Volt Rating (This Standard, from Standards Proposal No. 558, is a revision of RS-165)—80 cents. RS-207—Television Tuner Performance Presentation and Measurement (This Standard, from Standards Proposal No. 560, is new material)—25 cents. RS-210—Terminating and Signaling Equipment for Microwave Communications Systems—Part I: Telephone Equipment (This Standard, from Standards Proposal Nos. 518 and 533, is new material)—$1.10. RS-211—Dimensional Characteristics of Phonograph Records for Home Use—78, 45, 33⅓ RPM (This Standard, from Standards Proposal Nos. 564, 565, and 572, is a revision of REC-103)—60 cents. RS-212—Numbering of Electrodes and Designation of Units in Electron Tubes (This Standard, from Standards Proposal No. 569, is a revision of ET-113)–25 cents.

*(Continued on page 48A)*

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* The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of July 28, and August 4, 11 and 18, published by the Electronic Industries Association whose helpfulness is gratefully acknowledged.

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...for Complete Reliability Under Severe Environmental Conditions

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TYPE A10-W TRIMMER POTENTIOMETERS
Wire Wound, Precision, Sub-Miniature, Ruggedized

A10-W Trimmer Potentiometers are completely sealed for high temperature operation; with ruggedized construction, they provide reliability under the most severe operating conditions. Four designs available for the demanding space requirements of precision circuitry.

- Rated at 1 watt up to 70° C. ambient temp.
- Resistance range from 1 ohm to 30K ohms.
- Standard tolerance: ± 5%, closer tolerance available.

**RESOLUTION:** .1% to 1%, depending on resistance.

**OPERATING TEMPERATURE RANGE:** −55° C. to 150° C.

**INSULATION RESISTANCE:** 1000 megohm minimum at 500 VDC at room temp.

**END RESISTANCE:** Not greater than 4%.

**TEMPERATURE COEFFICIENT OF TRIMMER UNIT:** Within ± 100 parts per million.

**SUB-MINIATURE SIZE:** .220 X .312 X 1.250 inches.

**SCREW ADJUSTMENT:** Fully adjustable throughout 25 turn range.

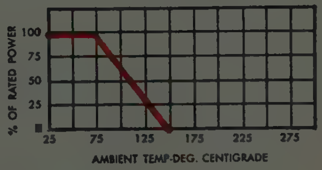
**SHAFT TORQUE:** 7 inch/ounce maximum.

**SAFETY CLUTCH:** Clutch arrangement on movable wiper contact prevents breakage due to over-excursion.

**SELF-LOCKING ADJUSTMENT:** Wiper will not shift under severe vibration or shock.

**MILITARY SPECIFICATIONS:** Surpasses applicable paragraphs.

TYPICAL DERATING CURVE



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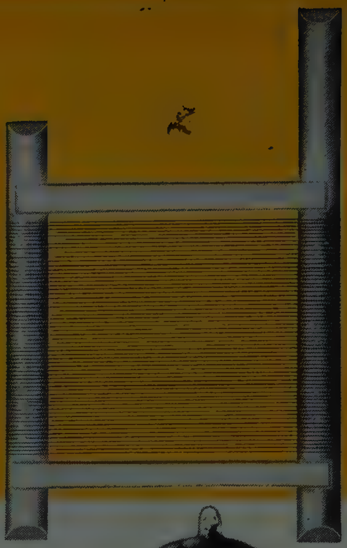

*. . . the world's most modern broadband amplifier pentode*

**Amperex 6688**

*a RELIABLE premium-quality tube for military systems requirements and exacting industrial applications*

- completely ruggedized construction
- figure of merit of 250 Mc as broadband amplifier
- saves entire stages in IF and video amplifiers
- improves signal-to-noise ratio
- preferred for new equipment design, particularly airborne applications
- long-life cathode

**TYPICAL OPERATION**

| | |
|---|---|
| Plate Supply Voltage | 190 volts |
| Grid Supply Voltage | +9 volts |
| Cathode Bias Resistor | 630 ohms |
| Plate Current | 13 ma |
| Transconductance | 16,500 μmhos (min. 14,200; max. 18,800) |
| Amplification Factor | 50 |
| Equivalent Noise Resistance | 460 ohms |
| Grid Voltage (rms) | 0.5 volt |

***** *It's the*

**FRAME GRID CONSTRUCTION**

*that makes the difference!*

The frame grid is the closest approach to the ideal "physicist's grid"— the grid with only electrical characteristics but no physical dimensions.

*It results in:*

- higher transconductance
- tighter $G_m$ and plate current tolerance
- low transit time
- low capacitances
- lower microphonics
- rugged construction

**Amperex FRAME GRID**

The grid-to-cathode spacing tolerance is determined by the carefully controlled diameter of grid support rods (center-less ground) and by frame crossbraces between these rods. Extremely fine grid wire eliminates the "island effect" usually encountered in conventional tubes with equally close grid-to-cathode spacing. Rigid support of fine wires reduces mechanical resonance and microphonics in the grid.

**CONVENTIONAL GRID**

Grid-to-cathode spacing tolerance depends on accuracy of grid dimension, obtained by stretching on a mandrel, and on tolerances of holes in top and bottom mica rod supports. Diameter of grid wire must be large enough to be self-supporting.

Other **Amperex** Premium Quality (PQ) frame grid tubes available in production quantities:

5847............broadband amplifier pentode
6922............ruggedized high-gain twin triode

*plus other PQ and frame grid tubes for special reliability requirements and exacting industrial applications*

*ask* ***Amperex*** *about premium-quality tubes for special reliability requirements*

Semiconductor and Special Purpose Tube Division
AMPEREX ELECTRONIC CORP.
230 Duffy Avenue, Hicksville, L. I., N. Y.

In Canada: Rogers Electronic Tubes & Components, 116 Vanderhoof Ave., Toronto 17, Ontario

## Industrial Engineering Notes

(*Continued from page 47A*)

### GOVERNMENT

**The Federal Communications Commission last Friday sent a letter to Rep. Oren Harris (D., Ark.), Chairman of the House Commerce Committee, in which it refused to call off its schedule of accepting applications for subscription TV authorizations within 30 days from the adjournment of the 85th Congress.** Though the FCC will accept trial pay-TV applications it will not grant any such applications until the "*sine die* adjournment of the First Session of the 86th Congress" in order to afford an opportunity for "the conduct of Congressional hearings on the subject and for the adoption of such legislation as Congress may deem appropriate," the Commission said. If no action is taken by the Congress the FCC will then be free to go ahead with its scheduled plans, Commission spokesmen said . . . **Major air navigation and air traffic control facilities programmed by the Civil Aeronautics Administration for the current fiscal year will amount to $175 million—the largest appropriation of its kind in CAA history.** The program provides for installation of long-range radar units for five CAA air route traffic control centers; 19 airport surveillance radars (ASR); instrument landing systems (ILS) at 19 new locations; 23 new airport traffic control towers; installation of 62 VORTAC short-range navigation systems; integration of 150 existing VOR with TACAN; and an air traffic control operational analysis simulator for the CAA Technical Development Center at Indianapolis.

### MARKETING

**TV production in June totaled 377,090 compared with 266,982 TVs made in May and 543,778 TV receivers produced in June 1957.** The number of TV sets made with UHF tuners totaled 36,811 in June compared with 29,406 made in May and 72,766 such receivers made during June 1957. Cumulative output of TVs capable of receiving UHF declined to 209,726 during the first half of this year from the 354,849 such sets made at this time last year. Cumulative TV production during the first six months of this year amounted to 2,167,930 compared with 2,722,139 TV receivers made in the same period last year. Radio receiver production in June totaled 774,424 including 235,433 automobile radios compared with 654,803 radios made in May, which included 185,616 auto sets, and 1,088,343 radios produced in June 1957 which included 416,058 auto radios. Cumulative radio receiver production during the first half of this year totaled 4,961,293 including 1,464,519 auto receivers, compared with 7,187,294 radios made during the like six-months period last year, which included 2,834,676 auto radios. . . . **Factory sales of television picture tubes in June increased substantially over May while receiving tube sales declined slightly during the**

(*Continued on page 50A*)

OUTPUT VOLTAGE
LAMBDA
REGULATED POWER SUPPLY

**Guaranteed: around-the-clock performance for five years**

Freedom from worry about major maintenance or extensive replacement for *five full years.* That's the guarantee given with every Lambda power supply—the first such guarantee in the electronics industry. It proves the point engineers keep making in preference studies: When operating conditions make dependability a "must," they specify Lambda... To check the full Lambda line yourself, send for the latest catalog.

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# IMPULSE

A DIGEST OF NEW DEVELOPMENTS IN ELECTRONICS AND AUTOMATION

PUBLISHED BY ROME CABLE CORPORATION, ROME, N. Y.
*PIONEERS IN INSTRUMENTATION CABLE ENGINEERING*

**TALKING ROAD MAP**—A new "accessory" to tempt automobile buyers of the future might be an electronic navigational computer system like the one now being developed for the Army to be used on tanks and other vehicles. Operator merely feeds map co-ordinates of position and destination into the system. To find the shortest way home, he keeps the vehicle-heading indicator superimposed on the destination-heading indicator.

**ELECTRONIC POSTMAN**—An electronic mail sorter now being developed and tested for the Post Office Department represents significant advancements in computer equipment for commercial marketing. Presently, it's mostly a military market for electronic computers. But by 1960, industry expects problems like optical character sensing to be solved. Rome Cable Corporation can help you solve your wire and cable problems. Send for our free bulletin—Bulletin RCD-400—which covers telemetering, data recording, circuit control testing, and electronic computer cable, or get in touch with the Rome Cable representative nearest you and ask him for a copy.

**ELECTRIC-POWERED SPACEFLIGHT**—Basic research on an electric space engine is 75% complete, according to AVCO Manufacturing. AVCO has been working for five years in the growing scientific field of MHD—magnetohydrodynamics. MHD is based on the fact that gases, when heated to a certain point, become electrically charged and may be controlled by magnetic fields. Still five to ten years away, the new engine could produce thousands of pounds of thrust per pound of fuel.

**ELECTRONIC REFRIGERATORS**—Word comes from at least two manufacturers about work being done in development of electronic refrigerators that cool without moving parts. Units operate on Peltier effect—known to cause a junction of two metals (antimony and bismuth) to cool when current is reversed. Problem to now has been the small cooling capacity due to heat dissipation by conductors. Knowledge of new semiconductors available, however, is furthering development.

**CABLEMAN'S CORNER**—Your source of special wire and cable must be more than just "satisfactory." Being able to deliver the material on time is, of course, the duty and obligation of *every* manufacturer. But, when you're on a spot, you need a cable supplier that you can depend on.

At Rome Cable Corporation, we strive to establish normal delivery promises and *to meet them*. Even so, today's rather hectic conditions sometimes require that a special emphasis be placed on getting a cable order through as soon as possible. This we have done!

Recently, a customer required "the best possible" shipment on a vital instrumentation cable. Rome's employees worked round-the-clock to produce, inspect, and deliver this cable by the customer's request date. And, even with this special emphasis, *every* rigid test requirement was met. Naturally, this was an unusual case. It isn't necessary to do this on every order. But it points up the fact that Rome Cable not only stands for quality—it stands for dependability.

Don't take a chance on just anyone to meet *your* quality, reliability, and service needs. Call on a Cable specialist. Our address is Dept. 430-D, 421 Ridge Street, Rome, New York, Phone: Rome 3000.

*(Continued from page 48A)*

**month. Cumulative sales of both types of tubes dropped from the level of the first six months last year.** Producers sold 36,270,000 receiving tubes in June with a value of $31,445,000 compared with 36,540,000 units valued at $31,406,000 in May and 35,328,000 tubes with a value of $31,314,000 in June 1957. Cumulative receiving tube sales for the first six months of this year totaled 190,406,000 with a value of $166,269,000 compared with $221,175,000 tubes worth $190,461,000 sold during the first half of last year. Television picture tube makers sold 725,846 tubes in June valued at $14,203,381 compared with 560,559 such tubes worth $11,237,147 sold in May and 1,104,013 TV picture tubes worth $19,981,319 sold in June 1957. . . . **Factory sales of transistors increased in June over the May level of sales.** Cumulative sales of these semiconductor devices during the first half of this year increased substantially over the high level recorded during the like 1957 period. Factory sales of transistors in June totaled 3,558,094 with a dollar value of $8,232,343 compared with 2,999,198 of these semiconductor devices valued at $7,250,824 sold in May and 2,245,000 units valued at $6,121,000 sold in June a year ago. Cumulative sales of transistors during the first six months of this year totaled 18,452,324 units valued at $42,845,056 compared with 11,199,300 units valued at $31,249,000 sold during the first half of 1957. . . . **Cumulative TV picture tube sales in the six-month period totaled 3,689,587 valued at $73,228,119 compared with 4,814,659 tubes worth $86,987,031 sold in the like six-month period last year. . . . Factory production of both radio and television receivers in June increased over the May output of these items but declined from the number of both radio and TV receivers produced in June a year ago.** Output during the first six months of this year was considerably under the first half production figures recorded by EIA last year.

## MILITARY ELECTRONICS

**Three reports of electronics research for the Armed Forces, one describing a new transistorized commutator-encoder, one reviewing a study of the high-temperature resistivity of ceramics, and the third describing a comparative study of silicon and germanium transistors, have been released for industry use through the Office of Technical Services, Commerce Department.** The reports, their price and number follow. Copies can be obtained from OTS, Commerce Department, Washington 25, D.C. "A Solid-State Commutating and Pulse-Width Encoding Circuit," PB 131486, 75 cents. "Research & Development of High Temperature, Radiation Resistant Fixed Transistors," PB 131655, $1 each. "A Comparison of Silicon and Germanium Low-Power Audio Alloy Transistors," PB 131364, 75 cents.

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With recovery to 400 K ohms (minimum) in 1 microsecond...Hughes high-speed silicon diodes reliably meet the quick recovery requirements of most germanium types, and in addition, stand up under high voltages at high temperatures. In fact, the breakdown voltages increase with temperature...thereby providing maximum protection when temperatures reach unexpected levels. With this order of reliability, Hughes quick recovery silicon diodes assure dependability under the most severe operating temperatures.

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# NEWS New Products

## Coaxial Ferrite Load Isolators

Made possible by a new design technique which permits the insertion of ferrite strips directly in the coaxial line, a new series of Uniline Load Isolators has been designed by **Cascade Research Div., Monogram Precision Industries, Inc.,** 53 Victory Lane, Los Gatos, Calif. which eliminates bulky transitions to and from waveguide formerly required for isolators in coaxial systems.

Identified as the Model CN121 Series, the units are all $6\frac{5}{8}$ inches long, have a maximum diameter of $\frac{1}{2}$ inches, and weigh less than 1.5 pound. They are intended for use in low- and medium-power coaxial systems. Normally, they are supplied with female type N connectors on both input and output terminals.

Following are performance characteristics of the four: CN121, operating from 4.0 to 7.0 kmc provides 10 db isolation; CN121A, operating from 5.0 to 7.0 kmc provides 20 db isolation; CN123, operating from 2.7 to 2.9 kmc provides 20 db isolation; CN124, operating from 2.5 to 3.8 kmc provides 10 db isolation. All four exhibit insertion loss of 1.0 db.

Units in the CN121 Series are priced at **$185.**

## Solid Tantalum Capacitors

New Type S-T-A (solid tantalum) capacitors for higher working voltages have been announced by **Fansteel Metallurgical Corp.,** North Chicago, Ill.

**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.**

Four new capacitors are available: Cat. No. 179, rated at 0.7 $\mu$f, 50 wvdc; Cat. No. 181, rated 0.6 $\mu$f, 60 wvdc. These capacitors are in subminiature size, 0.175 inch diameter, 0.250 inch long, exclusive of leads. Cat. No. 479, rated 1.4 $\mu$f, 50 wvdc and Cat. No. 481, rated 1.2 $\mu$f, 60 wvdc, are only slightly longer: 0.175 inch diameter, 0.375 inch long.

Previous Type S-T-A capacitors were limited to a maximum of 35 working volts. Like other S-T-A capacitors, the new higher voltage units have an operating temperature range from −75°C to +85°C. Maximum leakage current at 25°C does not exceed 3 microamperes.

Full specifications and details are given in Bulletin 6.112–3, available upon request.

## Ferrite Load Isolator

Used to provide substantial isolation between a microwave source and its load with negligible loss in transmitted power, the new Uniline Ferrite Load Isolator Model XL157, developed by **Cascade Research Div., Monogram Precision Industries, Inc.,** Los Gatos, Calif., removes the reactive loading effect caused by long transmission lines or the frequency pulling of the magnetron or klystron.

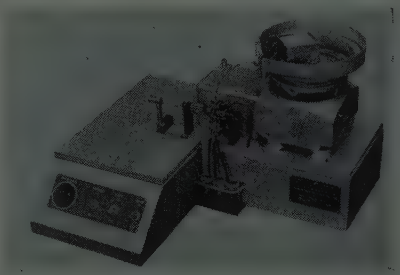
Uniline
XL157

High-power operation is achieved through the use of high Curie-temperature ferrite materials with broad surfaces in close contact with the waveguide wall to provide good heat conduction. The XL157 is of rugged construction and conforms with military requirements.

Operable over the band 8.5 to 9.6 kmc, it gives 15 db isolation with an insertion loss of 0.5 db. Input vswr into a flat load is 1.15. Peak power with a 2 to 1 mismatch is 300 watts. Operating throughout the temperature range −55 to +125°C, the XL157 has UG-51/U flanges to mate with RG-51/U waveguide.

## High Speed Core Test

New techniques in magnetic core testing were demonstrated by **Telemeter Magnetics, Inc.,** 2245 Pontius Ave., Los Angeles 64, Calif. at the IRE Special Technical Conference on Magnetics during the week of August 4 at the Hotel Statler in Los Angeles. Using a new automatic core handler, the company showed how they grade 50-mil cores at the rate of 12,000 cores per hour.



The core handler, developed for Telemeter Magnetics by the Ramsey Engineering Co. of St. Paul, Minnesota, moves a core into position, holds it there by vacuum, inserts a coaxial probe, and makes individual drive and sense circuit connections to permit testing.

Cores are then tested for switching time, peaking time, noise level, output emf, and "knee." Test duration is 0.1 second and during that time, 100 successive sets of tests are performed. The core is then released into one of three containers according to grade. The entire operation is automatic.

The electronics which make such rigorous high speed testing possible were developed by TMI engineers. Telemeter Magnetics, Inc. manufactures a variety of storage and switching cores and also makes core arrays, complete memories, and data handling systems.

## Electrometers Bulletin

A new bulletin now available from **Applied Physics Corp.,** 2724 South Peck Rd., Monrovia, Calif., describes the Cary line of electrometers and discusses their applications and specifications. Cary Electrometers are used for measuring very small currents, charges and voltages such as required in making radio-activity measurements, $C^{14}$, $H^3$ and $S^{35}$ determinations, ion currents in mass spectrometry, $P^H$ determinations.

Write to the manufacturer for Bulletin 130.

*(Continued on page 108A)*

550 Mc
60,000 Mc

## RAYTHEON REFLEX KLYSTRONS

# from 550 to 60,000 Megacycles

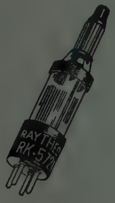
More than 70 Raytheon reflex-type klystrons for local oscillator, signal generator and transmitter applications.

Raytheon produces more reflex klystrons than all other manufacturers in the world combined . . . one important reason why Raytheon klystrons have established a matchless record for reliability and proved performance in thousands of installations.

Equipment designers are welcome to call on our Application Engineer Service. Write for consolidated data booklet presenting comprehensive characteristics of the *complete* line of Raytheon klystrons, magnetrons and special tubes. There is no cost, or obligation.

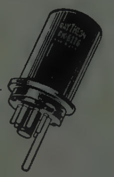
### 3 TYPICAL RAYTHEON REFLEX KLYSTRONS

**RK-5721** — Velocity variation oscillator designed for use with a coaxial cavity in CW or pulsed operation over the 4290 to 11,000 Mc range for signal generator and special local oscillator applications.



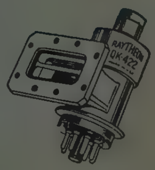
| | |
|---|---|
| Heater Input @ 0.58 A | 6.3 V |
| Reflector Voltage Transit Mode | 2¾ cycles |
| Frequency Range | 4290-8340 Mc |
| DC Resonator Input @ 20 mA | 1000 Vdc |
| DC Reflector Voltage | -50 to -625 V |
| Electronic Tuning (Half Power) Frequency Change | 12 Mc min. |
| Reflector Modulation Sensitivity (8340 Mc) | 0.1 Mc/volt |
| Power Output (Average CW) | 160 mW |

**RK-6116** — A ruggedized thermally tuned oscillator of the integral cavity type designed for CW operation in the 8500 to 9600 Mc range with an average power output of 30 mW.



| | |
|---|---|
| Heater Input @ 0.52 A | 6.3 V |
| Tuner Heater Current | 0.80 A |
| Frequency Range | 8500-9660 Mc |
| Resonator Input @ 25 mA | 300 Vdc |
| Reflector Voltage (max. Po @ 8550 to 9660 Mc) | -60 to -145 Vdc |
| Thermal Tuning Time 8500-9660 Mc | 2 seconds |
| Electronic Tuning Range @ 9080 Mc | 100 Mc |
| Power Output 8500-9660 Mc | 26 to 34 mW |

**QK-422**—A mechanically tuned velocity variation oscillator designed for CW operation in the 7125 to 8125 Mc range in microwave relay systems.



| | |
|---|---|
| Heater Input @ .44 A | 6.3 V |
| Frequency Range | 7125 to 8125 Mc |
| DC Resonator Input @ 32 mA | 300 Vdc |
| DC Reflector Voltage (max. Po @ 7125 to 8125 Mc) | -130 to -210 Vdc |
| Power Output 7125 to 8125 Mc | 100 mW min. |
| Electronic Tuning (to half power points) @ 7600 Mc | 25 Mc min. |
| Modulation Sensitivity @ 7600 Mc (10 V pk. to pk. mod. volt.) | .5 Mc/V min. |

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## QUICKER — MORE ACCURATE — MORE RELIABLE CIRCUIT DESIGN

## CONDUCTANCE CURVE DESIGN MANUAL

*by Keats A. Pullen, Jr., Eng., D.*

This vacuum tube working manual for the engineer thoroughly ties together circuit equations and the concept of small signal parameters for use in circuit design. It provides a group of data, in table and graph form, so organized that it helps the user design circuits which function in the manner desired, *with a minimum of readjustment.* With the manual, the engineer can use small signal parameters to predict large signal performance with the following benefits:

- makes it possible to optimize a design so that a given performance can be obtained with minimum tube element dissipation by permitting point-by-point determination of dynamic operating conditions anywhere within a tube's rating. Life and circuit reliability are enhanced and experimental readjustment is minimized.
- clearer understanding of in what manner circuit performance changes when any circuit parameters are varied. Makes it evident that when a required performance can't be obtained without operating the tube near or at its peak, another tube type with greater power handling capability should be chosen.
- aids in the design of conservatively rated circuits for greater reliability.

**MANUAL DIVIDED INTO THREE PRINCIPAL SECTIONS**

① explanation of the special curves and their application in typical R-C amplifier designs.

② tables useful in making tube substitutions and tables to simplify the selection of tubes for given applications.

③ a special set of conductance curves for more than 70 of the most representative vacuum tube types used in all services. Includes low power and high power tubes, triodes and pentodes, and several mixer tubes.

**#210** 128pp., 8½x11", spiral stiff cover binding **$4.25**

## PHYSICS AND MATHEMATICS IN ELECTRICAL COMMUNICATION

*by James Owen Perinne, Ph.D.*

This is a profound and probing explanation of what happens in electrical circuits that contain resistance, inductance and capacitance. While it is a penetrating analysis, it is presented in an unusually lucid manner. The author demonstrates a talent for selecting that avenue of approach in analysis which leads to utmost clarity. The text contains numerous explanatory diagrams, many conceived by the author, that point out and simplify concepts that normally are considered complicated. Each graph, complete with point-by-point identifying nomenclature, illuminates the text. On a foundation of associated mathematics made completely understandable and replete with numerical examples, the author brilliantly ties together physical concepts and electrical communication. An entirely new approach is used in analyzing hyperbolic functions, exponential equations and related functions. Of special significance is the content of the graphical demonstrations of electrical behavior.

TABLE OF CONTENTS:

Conic Sections; Circle, Sine, Cosine, Areas, Simple Harmonic Motion; Elipse, Simple Harmonic Motion; Parabola, Simple Harmonic Motion, Mirror; Hyperbola, Area; Hyperbolic Sinh, Cosh, Tanh; Fundamental Considerations of Conic Sections; Natural Law of Geometric Retrogression, Exponential Equations, Attenuation, Decibels, Alternating Current Decay; Resistance, Inductance, Capacitance, Oscillating Circuits; Kelvin's Equation for Electrical Oscillations; Exponential Equations and Transient Curves in R, L and C Circuits; Exponentials, Vectors Series Expansion of Sine, Cosine, Sinh, Cosh; Applications of Sinh and Cosh; Infinitely Long Electrical Circuits, Use of Sinh and Cosh. #219, 8½" x 11", cloth bound, **$7.50.**

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# IRE People

**S. Edwin Piller** (A'48–M'55), a National Broadcasting Company radio engineer who volunteers his spare time as director of the First Army MARS Technical Network, recently received an award from the Chief Signal Officer of the U. S. Army Signal Corps.

The award was an engraved plaque which read as follows: "Presented to S. Edwin Piller, A2KPQ, for exceptional personal contribution to the Military Affiliate Radio System in the planning, organization and conduct of the First United States Army MARS Single Sideband Technical Net by J. D. O'Connell, Lieutenant General, Chief Signal Officer United States Army at the 10th ARRL National Amateur Radio Convention, Washington, D.C., 16 August 1958."

Mr. Piller, an active amateur radio operator for more than twenty-one years, conceived the idea of a single sideband technical network whose prime mission is "The Dissemination of Technical Knowledge by Radio Communication." Starting in September, the net resumes operation on the First Army Command Channel of 4030 kc each Wednesday at 9 P.M. (prevailing N.Y.C. time) and can be heard within a radius of 1000 miles of New York City. Outstanding specialists in the electronics field give talks followed by question and answer periods in an on-the-air forum. Net members call in by radio from various parts of the northeastern United States. Six leading radio and electronics magazines will carry the monthly speaker schedules.

❖

**Guy K. Patterson** (S'41–A'42–SM'48) has been appointed chief engineer of Sierra Electronic Corporation, a subsidiary of Philco Corporation. He will direct Sierra's engineering and laboratory programs, including product development. He previously was a project engineer with the company.

G. K. Patterson

Prior to joining Sierra in 1948, Mr. Patterson was on the engineering staff of the Federal Telecommunication Laboratories in New York City. An electrical engineering graduate of the University of Nevada, Mr. Patterson also holds a postgraduate degree from Stanford University.

❖

**Marvin Hobbs** (A'35–M'41–SM'43) consultant to the general manager, Stewart-Warner Electronics, Chicago, received a Distinguished Service award during the annual Alumni Reunion of Tri-State College, Angola, Ind. Mr. Hobbs, who graduated in 1930 with the Bachelor of Science degree in electrical engineering, received the award from the Alumni Association president, C. A. Wilken, vice-president, research and engineering, Rockwell Manufacturing Company, Pittsburgh, Pa.

The citation, read by Dr. Joseph E. Williams, Tri-State's vice-president in charge of academic affairs, described Mr. Hobbs as an "industrialist, electronics consultant, contributor to the defense systems of the United States, and as Defense Department representative in international conferences."

Mr. Hobbs has been a Defense Department representative at NATO conferences on electronics standardizations, and as member of the American Rocket Society, has attended international conferences on astronautics at London and Stuttgart.

❖

The appointment of **Walter Serniuk** (S'41–A'43–M'46–SM'50) as manager of the Amherst Engineering Laboratory of Sylvania Electronic Systems, a division of Sylvania Electric Products, Inc., has been announced by H. C. Tittle, manager of the division's Buffalo Operations. Mr. Serniuk will be responsible for directing the research and development programs of the laboratory, which specializes in the fields of communications and navigation systems and equipment, and is the major product engineering activity for complex electronic equipment developed at other laboratories in the division.

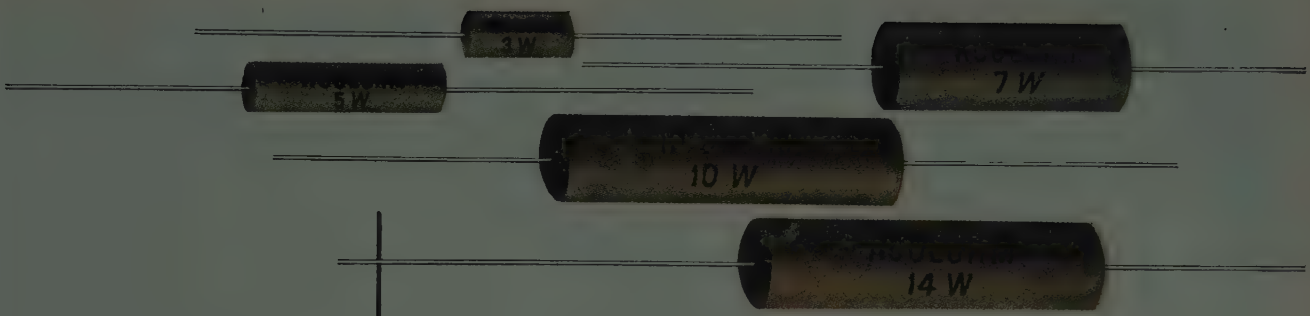
Joining Sylvania in 1942, Mr. Serniuk was associated with the development of special electronic devices for the armed forces, and later became head of the Systems Engineering and Techniques Section of the Sylvania Physics Laboratory in Bayside, N. Y. In July, 1953, he was one of four men who formed the company's Electronic Defense Laboratory in Mountain View, Calif. He was manager of equipment development there until April, 1957, when he became the first manager of the Reconnaissance Systems Laboratory in Mountain View.

He is a graduate of the University of Michigan and received the Master's degree in electrical engineering from Brooklyn Polytechnic Institute. He is a member of Sigma Xi, Tau Beta Pi, and the Scientific Research Society of America.

❖

**Frank B. Hartman** (S'50–A'53–M'54) has been promoted to staff engineer at the IBM Product Development Laboratory in Poughkeepsie, N. Y. He is engaged in the technical analysis of special problems for the Technical Planning Committee and also in the assembly and dissemination of

*(Continued on page 58A)*



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1. Leads are welded to drawn metal cap ends.
2. Ceron (ceramic insulated) resistance wire wound under controlled tension on special ceramic core. Makes possible multi-layer non-inductive windings as well as very high resistance value conventional windings.
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5. *Aged on load* prior to final test and inspection to stabilize resistance value and assure outstanding performance on load-life tests!

The advanced construction of these improved Koolohm Resistors allows them to operate at "hottest spot" temperatures up to 350°C. You can depend upon them to carry maximum rated load for any given physical size.

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(Resistive or Inductive Load)

| | ZJ39A 25 | ZJ39A 40 | ZJ39A 75 | ZJ39A 100 | ZJ39A 150 | ZJ39A 200 | ZJ39A 250 | ZJ39A 300 |
|---|---|---|---|---|---|---|---|---|
| Continuous Peak Inverse Voltage (PIV) | 25 | 40 | 75 | 100 | 150 | 200 | 250 | 300 V |
| Transient Peak Inverse Voltage (Non-recurrent > 5 millisec) | 35 | 60 | 100 | 150 | 225 | 300 | 350 | 400 V |
| RMS Voltage (Vrms) | 17.5 | 28 | 53 | 70 | 105 | 140 | 175 | 210 V |
| Average Forward Current ($I_F$) | Up to 16 amperes | | | | | | | |
| Peak One-cycle Surge Current (i surge) | 150 amperes | | | | | | | |
| Minimum Forward Breakover Voltage ($V_{BO}$) | 25 | 40 | 75 | 100 | 150 | 200 | 250 | 300 V |
| Maximum Forward Voltage ($V_F$ Ave.) | 0.75 Volts (Full Cycle Average) | | | | | | | |
| Maximum Reverse Current ($I_R$) | 5 ma (Full Cycle Average) | | | | | | | |
| Maximum Gate Current To Fire ($I_{GF}$) | 25 ma | | | | | | | |
| Maximum Gate Voltage To Fire ($V_{GF}$) | 3 Volts | | | | | | | |

# Finer performance of G-E low-current silicon rectifiers now within reach for all your requirements

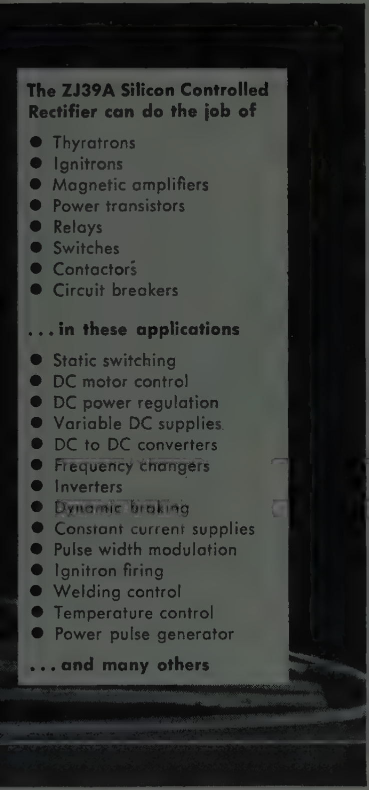
**MAXIMUM RATINGS AND SPECIFICATIONS**

| | PIV | RMS Voltage | Cont. Reverse D-C Volt | D-C Output (150°C Amb.) | D-C Output (50°C Amb.) | One-cycle Surge Current | Full-Load Forward Voltage Drop | Leakage Current | Ambient Operating Temp. |
|---|---|---|---|---|---|---|---|---|---|
| 1N536-40, 1N1095-96 series | 50-600 | 35-420 | 50-600 | 250 | 750 | 15 | 0.5 | 0.4-0.3 | 165 |
| 1N440B-445B series | 100-600 | 70-420 | 100-600 | 300-500 (100°C) | 300-750 | 15 | 0.5 | | 150-165 |
| 1N1487-92 series | 100-600 | 70-420 | 100-600 | 250 (125°C) | 750 (25°C) | 15 | 0.55 | 0.3 | 140 |
| 1N1692-95 series | 100-400 | 70-280 | 100-400 | 250 (100°C) | 600 (50°C) | 20 | 0.6 | 0.5 | 115 |
| | volts | volts | volts | ma | ma | amps | volts | ma | °C |

The time has come to reconsider possible applications of G.E.'s outstanding low-curren silicon rectifiers in the 1N536, 1N440 Serie (150°C line) . . . the 1N1487 Series (125° line) . . . and four recently added types i the 100°C area, the new 1N1692 Serie You'll find these devices more attractive t use than ever before—both in quality an price—with equally fine values in low-current silicon stacks. Stud-mounted units ar also available.

General Electric low-current silicon rectifiers are designed for maximum forward conductance at high operating temperatures High current loads are carried *without* external heat sinks. Reverse current at maxi

# obs, and more—prices reduced 50%



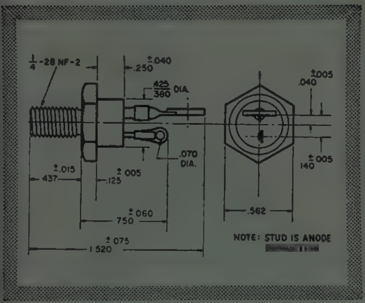
**The ZJ39A Silicon Controlled Rectifier can do the job of**

- Thyratrons
- Ignitrons
- Magnetic amplifiers
- Power transistors
- Relays
- Switches
- Contactors
- Circuit breakers

**. . . in these applications**

- Static switching
- DC motor control
- DC power regulation
- Variable DC supplies
- DC to DC converters
- Frequency changers
- Inverters
- Dynamic braking
- Constant current supplies
- Pulse width modulation
- Ignitron firing
- Welding control
- Temperature control
- Power pulse generator

**. . . and many others**



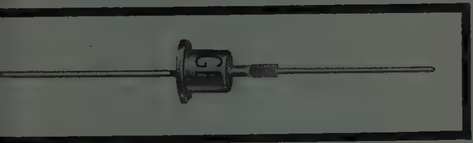
Price reductions in some cases greater than 50% will enable hundreds of new users to become acquainted with General Electric's new silicon controlled rectifier.

Neither a transistor nor a rectifier, this remarkable device combines features of both. In the reverse direction it acts like a standard rectifier. But it also blocks forward current until either a critical breakover voltage is exceeded or a signal is applied to the third lead. Then it switches to a conducting state and performs exactly like a forward-biased silicon rectifier.

The controlled rectifier offers the circuit designer current ratings comparable to thyratrons, blocking voltages useful in industrial circuits, complete control of current turn-on without complicated circuitry, and switching speeds in microseconds.

While in many ways similar to the gas thyratron, the controlled rectifier provides faster firing and recovery times, very low forward voltage drop, higher efficiency, absence of filament with attendant warm-up delay and power consumption, and higher-temperature operation.

Check the sample ratings and suggested applications at left. Application data and specifications will be sent on request.



mum junction temperature is maintained at an extremely low level, making these devices ideal for low-leakage applications.

Minimum forward voltage drop and a hermetically sealed case have produced silicon rectifiers whose reliability exceeds all existing MIL specs. A comparative evaluation shows that G-E devices have the *highest* resistance to thermal runaway at maximum full load operating temperatures. Thermal shock and temperature-cycle tests show a closer match of materials for expansion and contraction, to protect against breaking the hermetic seal and shattering the silicon pellet.

Ask your G-E semiconductor representative for the "big news" on low-current silicon rectifiers. Or write for more information.

## For fast delivery, lower prices, see your local G-E distributor!

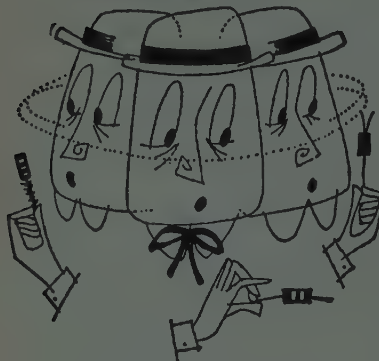
A recent check shows that General Electric transistors and rectifiers are being sold by local tube distributors for within pennies of the factory price on quantities less than one hundred—with the important difference that transportation charges are prepaid when you buy from your local G-E distributor.

Increased stocking of semiconductors by local G-E distributors means you now have *one* source for all your electronic needs. General Electric distributors can also furnish you with a wide variety of technical information, application data and spec sheets.

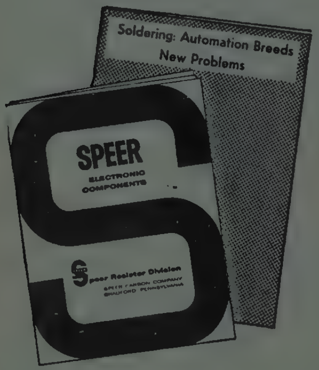
General Electric Company, Semiconductor Products Department, Section S5498, Electronics Park, Syracuse, N. Y.

**GENERAL ELECTRIC**

**Looking for the right resistor?**



*Call Speer for a complete line of fixed composition resistors, phenolic coil forms*



For detailed information on specifications, characteristics and applications ask for this catalog of Speer Electronic Components!

Automation Soldering your concern? Be sure to send for Speer's Bulletin on this subject.

**Other Speer Products for the Electronics Industry**

R. F. coils • chokes • fixed composition capacitors • Speer PAC made by Jeffers Electronics. • Also electronic tube anodes • contacts • rocket and missile parts • brushes • battery carbons • graphite plates and rods and graphite products for the steel and chemical industries.

SPEER RESISTOR DIVISION
SPEER CARBON COMPANY
Bradford, Pennsylvania

☐ Send the Speer Resistor Catalog.
☐ Send Automation Soldering Bulletin.

Name__________
Title__________
Company__________
Address__________
City_____ Zone_____ State_____

## IRE People

*(Continued from page 54A)*

information on new technical advances with emphasis on engineering improvements in the logical structure of computers.

He joined IBM in 1954 as a technical engineer, assigned to the design of the arithmetic and logical unit of the IBM's 705 computer. In 1957, he was on temporary assignment to an advanced computer project, participating in the investigation of circuit means for checking computer operation. He was assigned to the technical planning committee in November of that year.

Mr. Hartman had previously been a design engineer in the development of an information retrieval system at Yale University on a part-time basis during the academic year. He received the B.E. degree in 1952 and the M.E. degree in 1954, both from Yale.

A veteran of service with the U. S. Army, he is a member of Tau Beta Pi, AIEE, and the Institute of General Semantics.

❖

**Robert W. Pearson** (M'50), formerly deputy general manager for operations at American Machine and Foundry Company's Electronics Division in Boston, Mass., has been appointed director of manufacturing for AMF's Government Products Group, it was announced by Fred K. Powell, Jr., vice-president and Government Products Group executive.

R. W. Pearson

Before joining AMF, Mr. Pearson was with RCA at Camden, N. J., in 1948, as senior staff engineer in the production department, and later was administrator of mechanical design and manager, engineering standards and services. He was subsequently named manager of product planning. Prior to that he was superintendent of the Radio Division of Federal Television and Radio Corporation from 1946 to 1948. From 1937 to 1942 he was an industrial electronic control engineer with Westinghouse Electric Company, Pittsburgh, Pa.

During World War II, he served as research and development officer and as a contracting officer with the Signal Corps in Washington, D.C. and at Fort Monmouth, N.J. He held the rank of Lieutenant Colonel.

He received the B.S. degree from Drexel Institute, Philadelphia, Pa., in 1935, and the M.S. degree in electrical engineering from the University of Pittsburgh in 1941.

He is a member of the American Mathematical Society, and was formerly secretary of the Philadelphia Chapter of the Armed Forces Communications Electronics Association.

*(Continued on page 62A)*

Why do it Yourself?

**It Pays to Standardize on Jeffers R.F. Choke Coils**

You can save time, labor, and money by stocking the wide range of Jeffers R.F. choke coils just as you do resistors, capacitors, and other similar components. You can forget tedious, expensive hand assembly from miscellaneous forms, wires, and coatings by using standardized Jeffers coils, completely assembled for use.

Jeffers coils are well made, using insulated copper wire windings... husky molded jackets. All windings are soldered to leads... shorted end turns are completely eliminated.

Put these advantages to work in your circuits! Jeffers Electronics offers you . . . ready for delivery . . . a complete line of R.F. choke coils with a complete range of inductance values. Write today for our specification sheets.

**Other Jeffers Products**
fixed composition capacitors

**Other Speer Products for the Electronics Industry**
anodes • contacts • resistors
discs • brushes • molded notched* coil forms
battery carbon • graphite plates and rods

*Patented

JEFFERS ELECTRONICS DIVISION
SPEER CARBON COMPANY
Du Bois, Pennsylvania

*Other Speer Divisions:*
Speer Resistor, Speer Carbon Products, International Graphite & Electrode

*high reliability . . . extreme compactness . . .*

IN THE

# NEW SANBORN

# 850

## 6- & 8-CHANNEL DIRECT WRITING SYSTEM

If you want a practical direct writing system for straightforward recording in the range from DC to 100 cps — such as computer readout, telemetry recording — look what the new Sanborn "850" offers in compactness, reliability and operating convenience. A complete 8-preamplifier module with power supply, plus an 8-channel flush-front recorder package containing power amplifiers and power supply at rear, occupy only 24½" of "850" panel space.

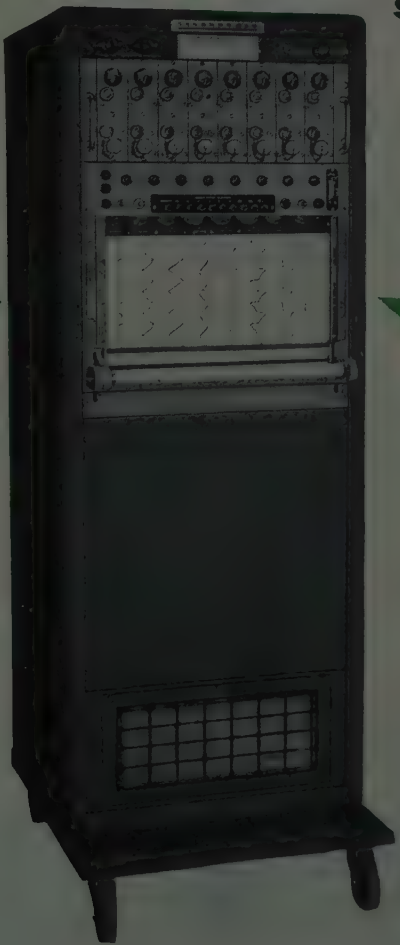
**PERFORMANCE** characteristics of an "850" include flat frequency response 0–70 cps, down 3 db at 100 cps (10 div. peak-to-peak amplitude) . . . thermal drift eliminated by current feedback power amplifiers . . . limiting at input to prevent amplifier saturation or cut off, so that damping is never lost . . . drift less than 0.2 div. for 20° to 40° C. changes, line voltage changes from 103 to 127 volts . . . gain stability better than 1% with 20° C. and 20 volt changes . . . linearity 0.2 div. over 50 divisions . . . clear, permanent, inkless recordings in true rectangular coordinates.

**IN RELIABILITY,** "850" features include fully transistorized power amplifiers and power supply . . . rugged galvanometers with low impedance, high current, enclosed coil assemblies and velocity feedback damping . . . JAN components wherever practical, such as MIL-T-27 hermetically sealed power transformers, MIL-approved electrolytics in power supplies, etc. . . . forced filtered air cooling for stable operation.

And in operating **CONVENIENCE,** an "850" system provides such advantages as nine electrically controlled chart speeds, selected by pushbuttons . . . a choice of interchangeable Preamplifiers (DC Coupling and Phase Sensitive Demodulator presently available, with others in development) . . . remote control of chart drive, speeds, timer and marker . . . monitoring connection points . . . a Recorder that loads from front and has built-in paper take-up and paper footage indicator.

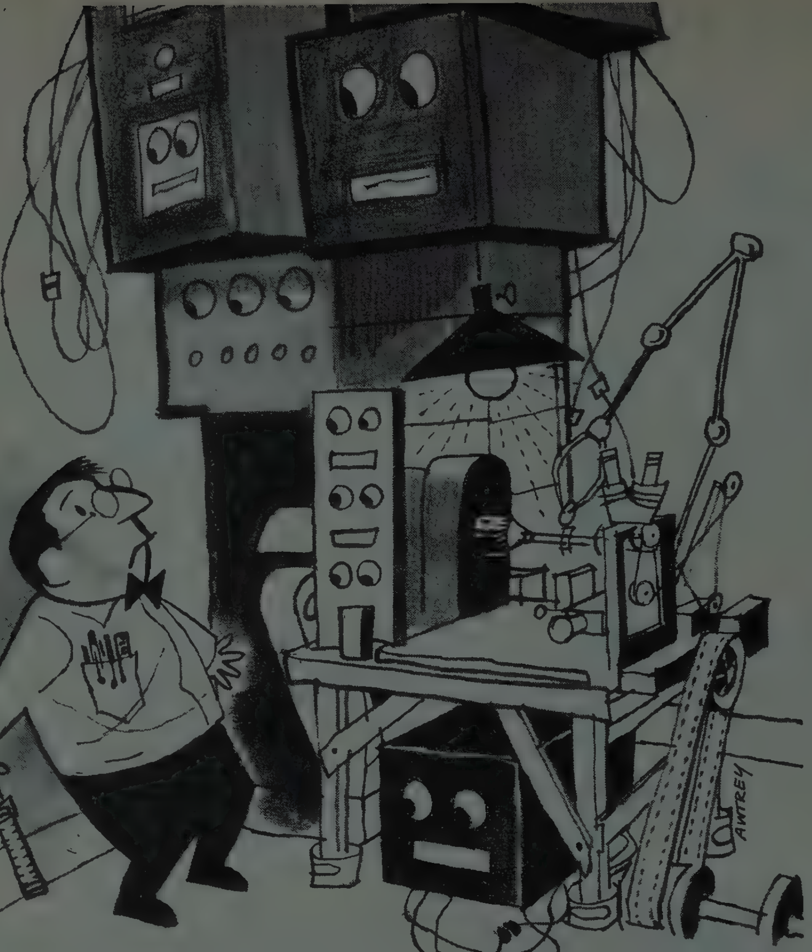
**SANBORN COMPANY**

175 Wyman Street, Waltham 54, Mass.



*Ask your local Sanborn Industrial Sales-Engineering Representative for complete facts — or write the Industrial Division in Waltham.*

(All data subject to change without notice)



## now you're all set to make pots!

If you're a fanatic about resolution, you *could* wind your own pots! Of course, it is a bit of a nuisance having to design and build those special winding machines able to deliver 0.1% linearity. Just dream up some fancy controls to keep the windings and spacing within microscopic tolerances, and you *might* make it!

But if you want to save all that fuss, just come to Ace. We've already designed and developed our own special winding machines, and they're all running nicely, turning out the kind of close linearity and high resolution through winding and spacing accuracy that *only* these machines . . . and Ace know-how . . . can produce. So don't build-it-yourself! For pots with the accuracy that pays off in performance, see your Acerep!

ACEPOT
500
250K
ELECTRONICS
SOMERVILLE

*Here's highest resolution in a standard sub-miniature pot: The Series 500 Acepot®. Single-turn, 1/2" size, from −55°C to 125°C. ±2% resistance tolerance, 0.3% independent linearity. Special prototype section insures prompt delivery.*

**ACE ELECTRONICS ASSOCIATES, INC.**
99 Dover Street, Somerville 44, Mass.
SOmerset 6-5130 TMX SMVL 181 West. Union WUX

Acepot® Acetrim* Aceset® Aceohm® *Reg. Appl for

---

## Operate your . . .

- tape recorder
- P. A. system
- portable TV set
- hand tools

FROM YOUR CAR, Boat or Plane!

with ATR

## INVERTERS

**FOR CHANGING YOUR STORAGE BATTERY CURRENT TO**

**A.C. HOUSEHOLD ELECTRICITY ANYWHERE . . . in your own CAR, Boat or Plane!**

**OPERATES**
*PORTABLE TV SET directly from your car!*

**OPERATES**
- *TAPE RECORDERS*
- *DICTATING MACHINES*
- *PUBLIC ADDRESS SYSTEMS*
- *ELECTRIC SHAVERS*

*directly from your car!*

**MAKE YOUR CAR, BOAT OR PLANE "A ROLLING OFFICE!"**

**OPERATES**
- *RADIOS*
- *RECORD PLAYERS*
- *MIXMASTERS, ETC.*

*directly from your car!*

mounted out of sight under dash or in trunk compartment

## ATR UNIVERSAL INVERTERS

**Especially designed to change 6 or 12 volt D.C. to 110 volt A.C. 60 cycles.**

**for . . .**
- EXECUTIVES
- POLICEMEN
- SALESMEN
- REPORTERS
- OUTDOOR MEN
- FIREMEN
- PUBLIC OFFICIALS

MODELS 6U-RHG (6 volts) 125 to 150 watts. Shipping weight 27 lbs. List price . . . . . . . . . . . . . $89.95
DEALER NET PRICE . . . . . . . $59.97
12U-RHG (12 volts) 150 to 175 watts. Shipping weight 27 lbs. List price . . . . . . . . . . . . . $89.95
DEALER NET PRICE . . . . . . . $59.97

*Write for literature on other Sizes and Models of ATR INVERTERS, priced as low as $9.95 list.*

**SEE YOUR JOBBER OR WRITE FACTORY**

✓NEW MODELS ✓NEW DESIGNS ✓NEW LITERATURE
- "A" Battery Eliminators • DC-AC Inverters • Auto Radio Vibrators

**AMERICAN TELEVISION & RADIO CO.**
*Quality Products Since 1931*
SAINT PAUL 1, MINNESOTA, U. S. A.

1
2
3
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9
0

*Presenting* **(hp) 524D Electronic Counter**

# New 8-decade numerical readout!
# New 5/10⁸ per week stability!

## SPECIFICATIONS

(Basic 524D without plug-ins)

**Frequency:**

- **Range:** 10 cps to 10.1 MC
- **Gate Time:** 0.001, 0.01, 0.1, 1, 10 secs or manual
- **Accuracy:** ± 1 count ± 0.000005%
- **Reads in:** KC. Automatic decimal

**Period:**

- **Range:** 0 cps to 10 KC
- **Gate Time:** 1 or 10 cycles of unknown
- **Accuracy:** ± 0.3% (1 period)
  ± 0.03% (10 period average)
- **Stan. Freq. Counted:** 10 cps, 1 KC, 100 KC, or 10 MC, or external
- **Reads in:** Secs, msec, µsec

**General:**

- **Registration:** 8 places (99,999,999 max.)
- **Stability:** 5/100,000,000. May be standardized with WWV or external 100 KC or 1 MC primary standard.
- **Display Time:** Variable 0.1 to 10 secs; or "Hold"
- **Input Voltage:** 1 v min, 1.5 v peak. Rise time 0.2 seconds max.
- **Input Impedance:** Approx. 1 megohm; 40 µµf shunt.
- **Price:** $2,150.00 f.o.b. factory.

*Data subject to change without notice*

**plus all these frequency and time measuring advantages!**

**Direct, instantaneous, automatic readings**

**Frequency coverage 10 cps to 220 MC***

**Time interval 1 µsec to 100 days**

**Resolution 0.1 µsec**

**High sensitivity, high impedance**

**No calculation or interpolation**

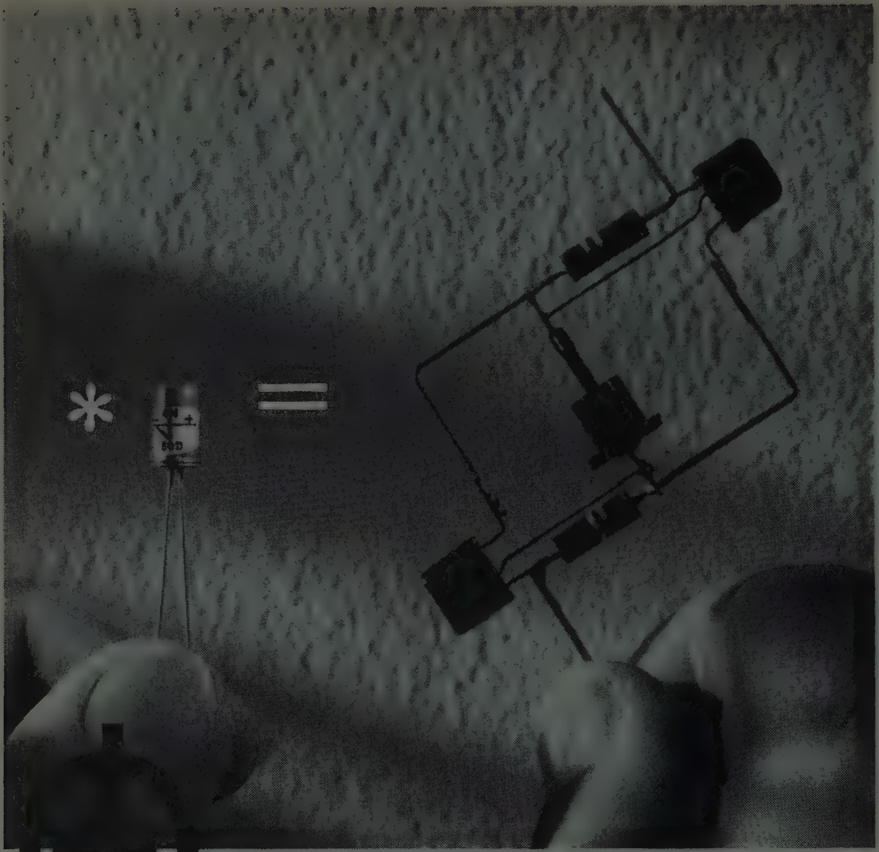
New convenience of uniform 8-decade numerical readout without meters — new 5 parts in $10^8$ stability simplifying standards and other microwave measurements — this is the capsule story of the new *-hp-* 524D Electronic Counter.

Electrically similar to the widely used *-hp-* 524B Counter, the new 524D provides for full frequency measurements from 10 cps to 10 MC and period measurements from 0 cps to 10 MC. Low cost plug-in units extend frequency measuring range to 220 MC, permit period measurements of over 10,000 periods, and increase sensitivity for precise measurement of weak signals. Still another plug-in provides for time measurements from 1 µsec to 100 days with 0.1 µsec resolution. When used with *-hp-* 540A Transfer Oscillator, the 524D will measure accurately to 12 KMC. For complete details, write or call your *-hp-* representative; or write direct.

*with plug-ins

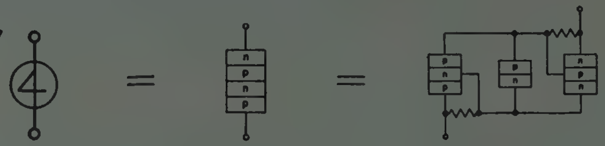
**HEWLETT-PACKARD COMPANY**
5022D PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
CABLE "HEWPACK" • DAVENPORT 5-4451
*FIELD REPRESENTATIVES IN ALL PRINCIPAL AREAS*

**(hp) world's most complete line of electronic counters**



SHOCKLEY 4-LAYER TRANSISTOR DIODE* SIMPLIFIES SWITCHING CIRCUITRY FOR COMPUTERS, TELEPHONY, CONTROL

HERE'S HOW



2-terminal switching diode | ...with 4 layers, alternate n and p type | ...can replace conjugate structure of 5 components

RANGE OF CHARACTERISTICS

$V_b$ (breakdown voltage) . 20-100v
$I_b$ (breakdown current) . <500 μa
$V_h$ (holding voltage) . . . <2V
$I_h$ (holding current) . . <50 ma
$R_h$ ("on" resistance) . <20 ohms (from 1—3 amps., voltage <1 volt plus 0.2 to 1.5 ohms times current)
Dissipation . . . . ∾100 mw
Time to close . . . <0.1 μsec
Time to open . . . <0.2 μsec

STANDARD TYPES AVAILABLE FOR DELIVERY NOW

| No. | $V_b$ Volts | $I_b$ μa | $V_h$ Volts | $I_h$ ma | $R_h$ ohms |
|---|---|---|---|---|---|
| 4N20D | 20±5 | <500 | <2 | <50 | <10 |
| 4N30D | 30±5 | <500 | <2 | <50 | <10 |
| 4N40D | 40±5 | <500 | <2 | <50 | <10 |
| 4N50D | 50±5 | <500 | <2 | <50 | <10 |

ENGINEERING DATA AND ASSISTANCE

Our engineering staff, under the direction of Dr. William Shockley, will undertake circuit problems in typical applications such as: sawtooth oscillators, pulse generators, bistable circuits, ring counters and various switching functions. Special types of transistor diodes are being developed to individual specifications. Technical information on request. Write to Dept. 1A-8J8.

*Invented at Bell Telephone Laboratories.

Shockley/Transistor Corporation
1117 California Avenue, Palo Alto, Calif.
A SUBSIDIARY OF BECKMAN INSTRUMENTS, INC.

## IRE People

*(Continued from page 58A)*

**Alfred S. Backus** (A'52) has been appointed director of Mycalex Electronics Corporation and Mycalex Tube Socket Corporation, affiliated companies of Mycalex Corporation of America, it was announced recently by Jerome Taishoff, president of the companies.

A. S. Backus

Mr. Backus is a leading production expert in the molding of glass-bonded mica and ceramoplastic materials. He has spent twenty years working with glass-bonded mica, beginning as foreman in charge of production at General Electric. In 1944 he joined Mycalex Corporation as plant superintendent, and later became plant manager and works manager. He was recently appointed acting general manager, the position he now holds in addition to his new one as director.

Mr. Backus is a member of the Society of Plastics Engineers and the Society of Metal Production.

❖

**W. R. G. Baker** (A'19–F'28) of Syracuse, N.Y., has been elected to the board of directors of Gulton Industries, Inc., Metuchen, N.J. The announcement was made by Dr. Leslie K. Gulton, president and chairman of the board. According to Dr. Gulton, "Dr. Baker's interest in our growth and activities has increased steadily over the past several years. Though his new association with us will include all areas of our research and production, Dr. Baker will direct his major interests to the fields of Astroelectronics, Thermoelectricity and Ultrasonics."

W. R. G. Baker

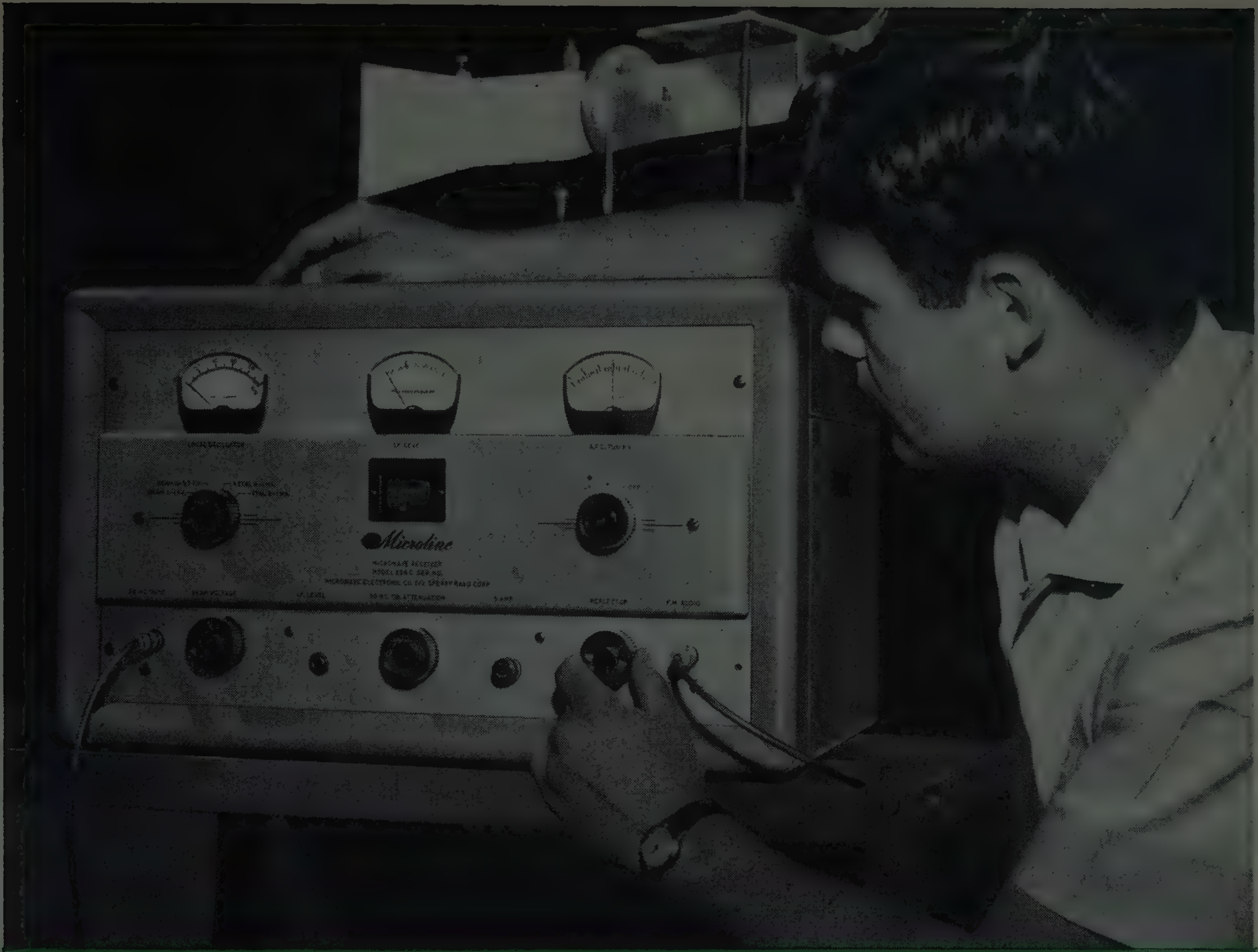
Prior to his retirement, Dr. Baker was vice-president of the General Electric Company responsible for all electronic activities for the company. He is currently vice-president of Syracuse University for Research, and president of Syracuse University Research Corporation.

He is a past president of the Electronic Industries Association and continues to serve as director of engineering. He is also a past president and treasurer of the IRE, and is chairman of the IRE Professional Groups.

❖

**Carl L. Christiansen** (S'50–A'51–M'56) has been promoted to area manager of the Magnetic Tape Devices Department of the IBM Product Development Laboratory at Poughkeepsie, N. Y. Recently named senior engineer, he is now in charge

*(Continued on page 66A)*



**MODEL 296C MICROWAVE RECEIVER**

IF frequency 30 mc
Bandwidth (overall) 1.3 mc at 3 db points
Gain IF amplifier 65 db min.
Pre-amplifier 30 db min.

Attenuation range, calibrated 0-80 db ± 0.2 db above 5 db at 30 mc
Self-contained local osc. power supply 600-800v at 50 ma., beam supply
Self-contained AFC System. Constant IF type with a time constant of about 0.2 sec.

For highly accurate measurements
at all microwave and UHF frequencies...

# SPERRY'S MODEL 296C MICROWAVE RECEIVER

This Sperry Microline* Receiver is a precision instrument of great accuracy enabling measurements at all microwave and UHF frequencies.

Model 296C can be used for measuring coupling and directivity of directional couplers, relative field strength, very high and very low VSWR, antenna patterns and as a general-purpose microwave laboratory receiver. In addition, this receiver was designed for use as a good secondary standard of attenuation.

A completely self-contained unit, it includes a 30-mc pre-amplifier, 30-mc IF amplifier, 30-mc calibrated attenuator, local oscillator power supply and AFC circuits. The 296C requires only the use of a local oscillator and an appropriate mixer for operation at any microwave or UHF frequency.

**TM Reg. U. S. Pat. Off.*

SPERRY MICROWAVE ELECTRONICS
COMPANY
CLEARWATER, FLORIDA
Division of Sperry Rand Corporation

**ADDRESS ALL INQUIRIES** *to Clearwater, Florida or Sperry Gyroscope offices in New York, Cleveland, New Orleans, Los Angeles, San Francisco, Seattle.*

# YOUR 1958 BUYING GUIDE TO SEMICONDUCTOR

## A PARTIAL LISTING OF INTERNATIONAL

## ...THE MOST EXTENSIVE

## ELECTRONIC TYPES FOR INDUSTRIAL AND MILITARY APPLICATIONS

### SILICON AND SELENIUM

### LOW CURRENT TYPES TO 1 AMP.

***SPECIAL MILITARY TYPES**
Special configurations and high reliability rectifiers for military applications may be obtained under our "Prescribed Reliability" Program. Address your inquiry to: Military Products Dept.

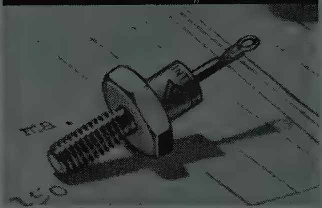
**MINIATURE SILICON POWER DIODES**

**Ratings: 100 to 600 PIV, Up to 500 ma.**
Specifically designed for missile and airborne equipment applications where miniaturization and reliability are prime factors. Hermetically sealed, all-welded, pigtail lead construction. Manufactured to meet the most rigid military requirements. Request **Bulletin SR-203**

**PIGTAIL TYPE SILICON POWER DIODES**

**Ratings: 50 to 600 volts PIV • 250 to 750 ma.**
An extensive line of silicon power diodes for military and industrial applications featuring all-welded, hermetically sealed construction. All designed and manufactured to meet the most rigid military requirements. For information on types for your application **Contact Factory**

**STUD MOUNTED SILICON POWER DIODES**

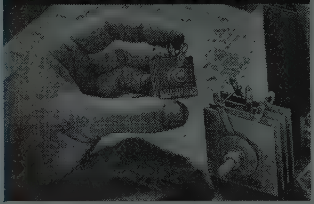


**Ratings: 50 to 600 volts PIV • 400 ma. to 1 amp.**
Industrial and military types including the 1N253, 1N254 and 1N255. Stud mounted, hermetically sealed, all-welded construction. Operating temperature range: −55°C to +150°C. Designed and manufactured to meet most rigid military specifications. **Bulletin SR-135C**

**SUB-MINIATURE SELENIUM DIODES**

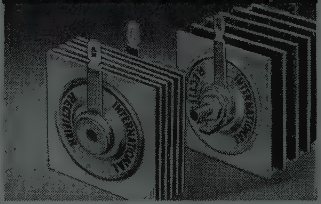
**Ratings: 20 to 160 volts • 100$\mu$a to 11 ma.**
Ideal components for bias supplies, sensitive relays, computers etc. High resistance, (10 megohms and higher at −10 volts). Excellent linear forward characteristics. Extremely small, low in cost. Encapsulated to resist adverse environmental extremes. Specify **Bulletin SD-1B.**

**SELENIUM RECTIFIER STACKS**



**Ratings: From 100 ma. to 50 Amps.**
Low forward voltage drop and low leakage characteristics make this series ideal for a wide variety of power applications. For details request **Bulletin C-439**, (26 volt cells); **Bulletin SR-160**, (45 to 52 volts per cell) and **Bulletin SR-152**, on high current density cells.

**SELENIUM TV AND RADIO RECTIFIERS**



**Ratings: 25 to 156 volts AC, 50 to 1,200 ma. DC**
The widest range in the industry! Designed for Radio, Television, TV booster, UHF converter and experimental applications. Input ratings from 25 to 156 volts AC and up. DC output current 50 to 1,200 MA. Write for application information. **Bulletin ER-178-A**

**SILICON TV RECTIFIERS**

**Ratings: 400 PIV, up to 750 ma.**
SD-500. A hermetically sealed, all-welded silicon junction rectifier offering maximum reliability in the high temperatures encountered in TV applications. Pigtail leads eliminate the need for brackets, blocks, etc., simplify installation. For complete data: **Contact Factory.**

**HIGH Q VOLTAGE VARIABLE CAPACITOR**

**Ratings: Q of 1000, 200 PIV DC**
*Semicap's* small size, light weight, high reliability and low power requirements make it ideal for automatic frequency control, frequency modulation oscillators and filter networks. All-welded hermetically sealed, shock-proof housing. Request **Bulletin SR-205.**

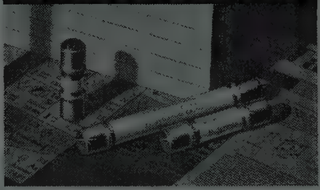
### SILICON AND SELENIUM

### HIGH VOLTAGE TYPES

**HIGH VOLTAGE SILICON POWER DIODES**

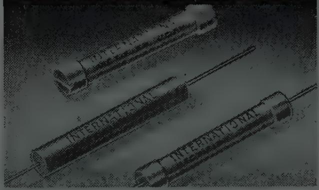
**Rating: 600 to 2400 volts PIV • 100 to 125 ma.**
Three types available. Hermetically sealed, pigtail construction. Style J rated at 600 to 1000 volts PIV at 125 ma. **Bulletin SR-138E** Styles K and L with PIV ratings from 600 to 2400 volts at 100 ma. dc output current are described in technical detail—**Bulletin SR-157.**

**HIGH VOLTAGE SILICON CARTRIDGE RECTIFIERS**



**Ratings: 1500 to 16,0000 volts PIV @ 45 to 440 ma.**
Especially suited for miniaturized military equipment where optimum reliability is a prime factor. Standard types for normal convection cooling and high current types for forced air or oil cooling. Hermetically sealed, metallized ceramic housing. Request **Bulletin SR-225**

**SELENIUM HIGH VOLTAGE CARTRIDGE RECTIFIERS**



**Ratings: 20 to 20,000 volts • 0.2 to 195 ma.**
Designed for long life and reliability in half-wave, voltage doubler, bridge, center-tap circuits, and 3-phase circuit types. Phenolic cartridges and hermetically sealed types available. Operating temperature range: −65°C to +100°C. For details specify **Bulletin H-2.**

**SPECIAL HIGH VOLTAGE TYPES**

**Rating: 12,500 volts PIV at 5 Amps.**
Illustrated above is a typical rectifier of advanced design produced by International Rectifier Corporation for military application. Data on ruggedized silicon substitutes for many standard vacuum tubes may be obtained from our Military Products Department.

# International

EXECUTIVE OFFICES: EL SEGUNDO, CALIF.

*The World's Largest Supplier of Industrial Metallic Rectifiers • Selenium • Germanium • Silicon*

ECTIFIERS FOR ALL DC REQUIREMENTS...FROM MICROWATTS TO MEGAWATTS

# ECTIFIER CORPORATION PRODUCTS

# INE OF QUALITY RECTIFIERS ON EARTH!

*All designed and manufactured to meet the most rigid military requirements!*

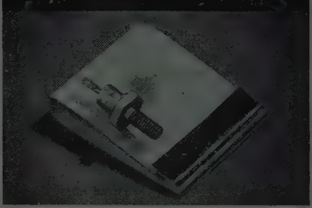
## POWER TYPES FOR INDUSTRIAL AND MILITARY APPLICATIONS

SILICON
AND
SELENIUM
MEDIUM
CURRENT
TYPES
O 150 AMPS.

**SILICON RECTIFIER STACKS**

**Utilizing junctions rated to 1.25 amps DC output**
These stacks consist of hermetically sealed junction diodes mounted on copper cooling fins, stacked to include the interconnections required for specific circuits. Junction ratings: 1.25 amps. DC output: 70 to 350 AC input volts rms. Request **Bulletin SR-137A**

**12 AMP. SILICON POWER DIODES**

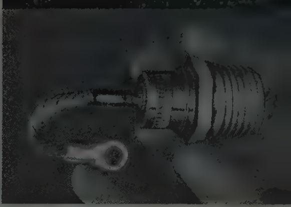


Conservatively rated to provide a substantial safety factor in industrial applications. Hermetically sealed, all-welded case construction provides reliability over a long life. Types available in a wide voltage range. For details **Contact Factory.**

**25 AMP. SILICON POWER DIODES**

**Rating: 50 to 500 volts PIV • 25 to 45 Amps.**
Advanced ceramic techniques assuring excellent thermal characteristics and mechanical stability are used in the production of these highly reliable, hermetically sealed rectifiers for military or industrial applications. For complete technical data, request **Bulletin SR-304**

**150 AMP. SILICON POWER DIODES**



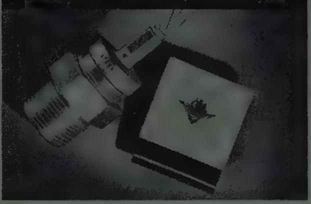
**Ratings: 50 to 800 volts PIV • 45 to 150 Amps**
An extensive series of standard and rever
polarity types. Optional mounting bases i
cluding machine thread and pipe thread type
Machine thread base types: **Bulletin SR-30**
Pipe thread base types. **Bulletin SR-30**
Complete stack assemblies: **Bulletin SR-30**

SILICON,
SELENIUM
AND
GERMANIUM
HIGH
URRENT
TYPES
O 670 AMPS.
ER JUNCTION

**SILICON RECTIFIER STACKS**

**Ratings: 45 to 150 Amperes per Junction**
Consisting of hermetically sealed junction diodes mounted on aluminum or copper cooling fins, stacked to include the interconnections required for specific circuits. Junction ratings: 45 to 150 amps average DC. Write for application data.

**250 AMP. SILICON POWER DIODES**

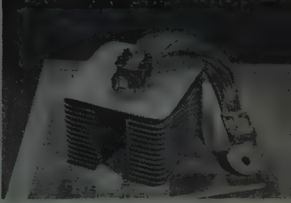


**Ratings: 50 to 500 volts PIV • 75 to 250 Amps.**
Standard and reverse polarity types offered in a series of machine thread and pipe thread mounting styles. Complete assemblies in all circuit configurations also available. Rugged construction and hermetic sealing assure long life and reliability. Ask for **Bulletin SR-305**

**SELENIUM HEAVY POWER RECTIFIERS**

**Ratings: 6 to 30,000 volts • 50 to 2,300 Amps.**
Specifically designed for industrial DC power needs. Patented construction features assure long life. Descriptive bulletins available are: **Bulletin C-349**, (26 volt cells); **Bulletin SR-160**, (45 to 52 volts per cell) and **Bulletin SR-152**, on high current density cells.

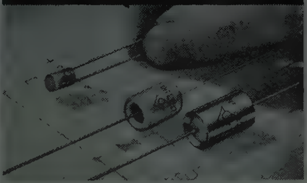
**GERMANIUM POWER RECTIFIER JUNCTIONS**



**Ratings: 500 amperes • 26 to 66 volts rms**
High capacity junctions especially designe
for high-current, low-voltage electrochemic
installations. Air cooled, these hermeticall
sealed junctions provide efficiency to 98.5%
Cast aluminum airfoil housing effects ma
mum heat transfer. For details **Contact Factor**

SPECIAL
SEMI-
CONDUCTOR
DEVICES

**SELENIUM CONTACT PROTECTORS**



**Complete series of AC and DC types.**
Designed to eliminate arcing and erosion across the contacts of relays, switches, etc. A complete series in each of three basic types: diode type, cartridge type and hermetically sealed types for industrial application. For complete data: **Bulletin SR-150-A**

**SILICON VOLTAGE REGULATOR ZENER DIODES**

**Ratings: From 600 milliwatts to 10 watts**
A complete series in 6 types. Miniature single junction types, multiple junction types and double anode units. 750 milliwatt and 1 watt types: **Bulletin SR-251**, 3.5 and 10 watt types: **Bulletin SR-252**, Multiple junction 5 watt types: SR-253, Double anode types: SR-254

**SILICON ZENER VOLTAGE REFERENCE ELEMENTS**

**Temperature compensated for stability to ±.001% °C**
Extremely precise units for power supplies and voltage sources. Temperature compensated for excellent stability over a temperature range of from −55°C to +150°C. Manufactured to meet the most rigid military requirements. Types 1N430, 1N430A, 1N430B. **Bulletin SR-255**

**PHOTOELECTRIC CELLS AND SUN BATTERIES**

**(Wide range of silicon and selenium types.)**
Self-generating cells available in standard an
custom sizes, mounted or unmounted. F
details on wide selection of selenium type
request **Bulletin PC-649**. Silicon solar cells
mounted and unmounted types are describe
in technical detail—specify **Bulletin SR-156.**

# Rectifier Corp.

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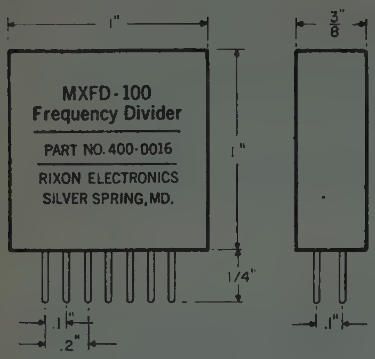
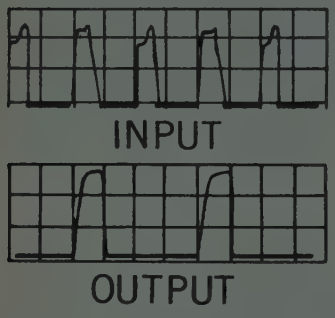
**ICAGO AREA OFFICE:** 205 W. Wacker Dr., FRanklin 2-3888
**EW ENGLAND AREA OFFICE:** 17 Dunster St., Cambridge, Mass., UNiversity 4-6520
**NNSYLVANIA AREA OFFICE:** Suburban Square Building, Ardmore, Penn., MIdway 9-1428

REPRESENTATIVES THROUGHOUT THE WORLD

FOR YOUR FREQUENCY DIVIDER PROBLEMS . . .





This simple device delivers one output pulse for every 2 input pulses. It can be directly cascaded for large division ratios. Feedback taps are provided to make any ratio possible.

Requires 20 to 30 volts DC at less than 15 ma per unit.

Useful for dividing output from frequency standards, in timing and clock circuits, plus many other applications.

Designed for direct assembly on printed circuitboards. Completely sealed. Will withstand a wide range of environmental conditions.

*Ask for Engineering Bulletin No. 56.*

RIXON
ELECTRONICS, INC.
2414 Reedie Dr.
Silver Spring, Md.

*(Continued from page 62A)*

of an advanced high-performance magnetic tape system development project.

He received the B.S.E.E. degree in 1951 from Rensselaer Polytechnic Institute, and served with the U. S. Navy, participating in the atomic bomb tests at Bikini in 1946. He was associated with Stavid Engineering Company as a junior engineer before joining IBM in June, 1951 as a technical engineer assigned to the 701 EDPM development group. Two years later he became a customer engineer for installation and maintenance of a 701 data processing system in Cincinnati, Ohio. He was advanced to associate engineer in September, 1954, and a month later was assigned to engineering work on the IBM 704 computer.

In June, 1955 he was placed in charge of testing the first production 704's and began early planning of the IBM 709 computer. As project engineer he continued 709 planning work until March, 1957 when he was appointed manager of high-density systems development in his present department. He was promoted to development engineer in September, 1957.

Mr. Christiansen is a member of Sigma Xi, the Professional Group on Electronic Computers, and the Mid-Hudson Science Advisory Council.

❖

R. SACKMAN

**Robert Sackman** (S'48–A'51), vice-president and general manager of Ampex Corporation, Redwood City, Calif., has been named to the board of directors of ORRadio Industries, Inc. ORRadio, a manufacturer of magnetic recording tape, and Ampex, a manufacturer of magnetic recording equipment, recently joined forces.

Mr. Sackman received his education in electrical engineering at George Washington University, Washington, D.C. During World War II he served in the U. S. Navy. For over twenty years he has been in the electronics industry gaining engineering and management experience, which has included directing a large research and development group in the Department of Defense, and specializing in data processing systems, magnetic recording devices, and communication equipment.

Since 1953 he has been with Ampex, as manager of the company's Washington, D.C. district office and vice-president and manager of the instrumentation division, prior to his present position.

Mr. Sackman is a member of Sigma Tau, the Armed Forces Communications and Electronics Association, the Instrument Society of America, and the American Management Association.

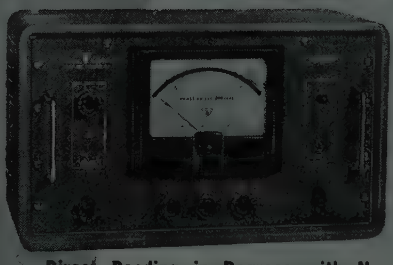
❖

*(Continued on page 68A)*

PRECISION
PHASE DETECTOR
TYPE 205

**Frequency Range:** 100 KC to 15 MC
**Accuracy:** 0.1° or 1%
**Resolution Time:** The smallest measured phase angle in degrees 8 x 10–11 x 360 x frequency in cps.
**Sensitivity:** Approximately 0.01 volt full scale.
**Price:** $445.00

PRECISION
PHASE METER
TYPE
405 SERIES



**Direct Reading in Degrees with No Adjustment.**
**Frequency Range:** 1 CPS. to 500 KC
**Accuracy:** ½° Relative, 1° Absolute
**Input Voltage:** 0.3 volt to 70 volts
**Phase Range:** 0-12°, 0-36°, 0-90° and 0-180°, full scale deflection
**Frequency Range:** Type 405 — 8 cps. to 100 kc; Type 405H — 8 cps to 500 kc; Type 405L — 1 cps. to 20 kc.
**Price:** Type 405 — $499.00; Type 405H — $538.00; Type 405L — $560.00.

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ELECTRONICS LAB., INC.
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249 TERHUNE AVE. • PASSAIC, N. J.

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# Now—guaranteed practical inductance limits for regular and frequency-stabilized permalloy powder cores

Call them frequency-stabilized or temperature stabilized, the important thing about these new molybdenum permalloy powder cores made by Magnetics, Inc., is our *guarantee* of core inductance within realistic limits. You can write—right now—for these guaranteed limits.

Filter circuit designers will take note that these guaranteed limits for permalloy powder cores are far tighter than those published before. Note also that they are guarantees on inductance which is the parameter of chief concern to the core user rather than on permeability.

This can save you dollars on your production line—by cutting down on adjustment of number of windings on coils.

And you know, too, that temperature stabilization eliminates difficult compensation problems.

But did you know that we guarantee these new inductance limits for all of our permalloy cores, whether stabilized or not? For *all* the facts, write us at *Magnetics, Inc., Dept. I-47, Butler, Pennsylvania.*

**MAGNETICS inc.**

Important Features of AMPHENOL MINNI E CONNECTORS

actual size

1

The "E" construction of AMPHENOL's miniature, multi-contact electrical connectors *pass* a *tough*, new *altitude-moisture resistance test* which accurately simulates performance conditions in new aircraft and missiles. Connectors are submerged in salt water and altitude-cycled to 80,000 ft., to 65,000 ft. and then returned to room ambient pressure. Cycle lasts one hour; test is comprised of ten cycles. At the end of the test AMPHENOL MINNI E's have a minimum insulation resistance of 1000 megohms, approximately ten times greater than that acceptable under MIL-C-5015C after moisture.

2

MINNI E's have *stainless steel* bayonet slots and pins, providing greater durability and eliminating the wear encountered with "hardcoat" and similar surface treatments of softer base metals.

3

Both #16 and #20 size socket contacts in MINNI E connectors *resist test prod damage*. The entering end of the socket has a one-piece stainless steel hood that excludes the entrance of a pin .005″ larger than the diameter of the mating male contact.

*AMPHENOL's Authorized Industrial Distributors stock MINNIE and other standard components, provide immediate service.*

AMPHENOL ELECTRONICS CORPORATION
*chicago 50, illinois*

AMPHENOL

## IRE People

*(Continued from page 66A)*

The appointment of **Jerome R. Steen** (M'36–SM'43–F'50) as engineering reliability specialist for the Ballistic Missile Early Warning System (BMEWS) Program of Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., has been announced by Richard W. Couch, Sylvania's BMEWS project manager. The division is responsible for the development of the data processing phase of BMEWS, a project assigned to the Air Force for the development and production of a "super radar" system to detect enemy intercontinental ballistic missiles.

J. R. STEEN

Mr. Steen received the B.S. degree in electrical engineering from the University of Wisconsin. He joined Sylvania in 1931 at Emporium, Pa., where he was in charge of receiving tube quality control. After serving in various quality control and commercial positions, he was named manager of quality control engineering for the Radio Tube Division in 1944.

In 1946 he was named corporate director of quality control and in 1954 became division manager in the same field for the Electronics Division. He subsequently was assigned to the Radio and Television and Semiconductor Divisions.

His previous experience was with General Electric Company, Schenectady, N. Y. and Bell Telephone Laboratories, New York, N. Y.

Mr. Steen is a Fellow of the American Society of Quality Control and a member of the American Institute of Electrical Engineers.

❖

**Jesse Y. Bowman** (S'42–A'44–M'55) has been appointed project manager for the guidance and control system of the Minuteman, the Air Force's forthcoming land-based, solid-propellant intercontinental ballistic missile system, incorporating improvements and advantages of the Atlas and Titan ICBM's. Autonetics, a division of North American Aviation, Inc., is developing the guidance and control system. A formal contract for the work is being negotiated with the USAF's Ballistic Missile Division.

Mr. Bowman has been associated with Autonetics in the missile guidance and control field for ten years. He participated in the engineering research and development of the first successful flight of the XN-1, the nation's first all-inertial autonavigator, in May, 1950.

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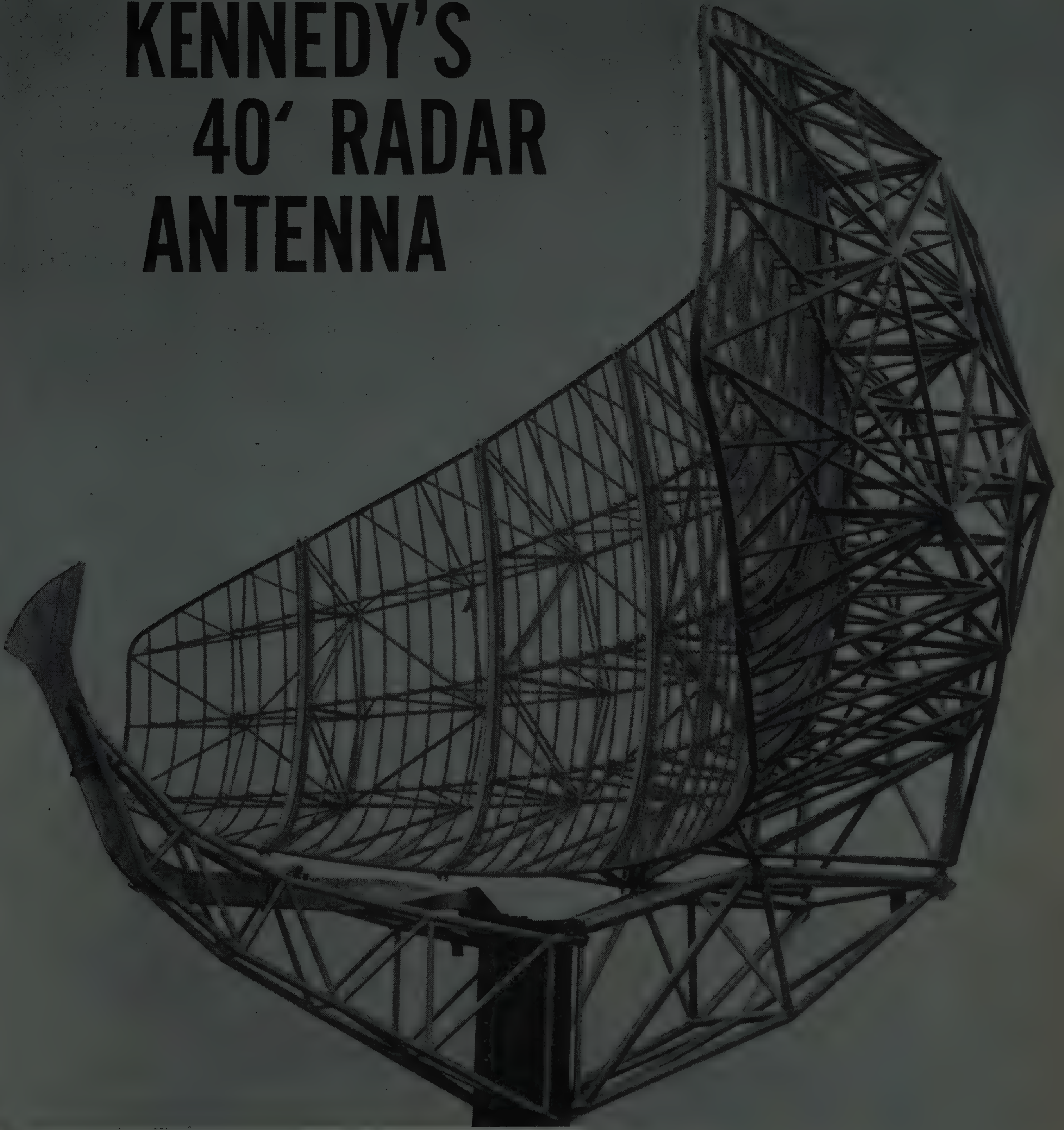
*(Continued on page 70A)*

*rugged and reliable…*

# KENNEDY'S 40′ RADAR ANTENNA



Developed and manufactured by Kennedy, this 40-footer is being used extensively by the CAA for air traffic control.

Ruggedness and reliability are two important reasons. It operates in winds to 80 knots with no ice, or to 40 knots if loaded with ice to 7 lbs. per square foot. When not operating it withstands 110-knot winds with no ice or 90-knot winds with 7 lbs. per square foot of ice.

Each of the 7 aluminum sections is interchangeable with corresponding sections of the same model. Weight of the sections is light enough to be easily handled during erection. Total weight is just over 1000 lbs.

ANTENNA EQUIPMENT

**D. S. KENNEDY & CO.**

Route 3A, Cohasset, Mass. EVergreen 3-1200

*West Coast Affiliate…*
**SATELLITE-KENNEDY, INC. of CALIFORNIA**
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*P.O. Box 1711, Monterey, California* - **FRontier 3-2461**

SUPER-FARRON f:0.87/76 mm

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for
dim
light
photography
and television...

SUPER
FARRON
F/0.87

76MM • 30° FIELD
40MM FOCAL PLANE

**Super-Farron**—an ultra high speed photographic objective having extremely fine correction over an unusually wide flat field. The advantages of its photographic speed of T/1.0 for operation under adverse light conditions are evident. It is available with standard infinity correction for direct photography, and it can be supplied corrected for 16:1 or 4:1 conjugates for special purposes. The Super-Farron is eminently suitable as an objective for Image Orthicon television cameras or for special 35mm photography.

*Technical data available on request*
*Specify Engineering Report No. 327*

Pat. No. 2,846,923

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*Precision Optics, Electronic and Scientific Instruments*
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*FREQUENCY-PERIOD METER*

*CMC's Model 211B* provides the most intelligent approach to production line and laboratory measurements of events-per-unit-time or period. The 211B combines a highly desirable large numeral (2¼" H), inline-inplane digital readout with a high speed electronic counter and time base.

The Model 211B incorporates an automatic decimal point indication and provision for driving the CMC Model 400B Digital Printer.

Write for 4 page brochure which gives complete technical and applications information. Address CMC, 5528 Vineland Avenue, North Hollywood, California. Dept. 4310.

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ALL SHAPES,
ALL ALNICO
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210 TAAFFE PLACE, BROOKLYN 5, N. Y.
Phone: MAin 2-0114

## IRE People

*(Continued from page 68A)*

**William J. Pietenpol** (M'52), a leading authority on the development and application of semiconductor devices, including the transistor, has been appointed vice-president and general manager of the Semiconductor Division of Sylvania Electric Products, Inc. He will be responsible for all divisional operations, including research and development, manufacturing, and marketing.

Born in Boulder, Colo., on July 15, 1921, he received the B.S. degree in electrical engineering from the University of Colorado. In 1949 he received the Ph.D. degree in physics from The Ohio State University.

From 1943 to 1946 he was engaged in development work on photoelectric tubes at RCA. In 1950 he joined Bell Telephone Laboratories, where he worked until assuming his present position. At Bell he was a member of the company's transistor design group, and in 1953 was appointed transistor development engineer at Allentown, Pa., responsible for the development of transistors for manufacture. In 1955 he became director of development, Semiconductor Devices, with responsibility for "taking new knowledge about semiconductor science and translating it into devices."

Dr. Pietenpol is a member of Sigma Xi, Tau Beta Pi, and Phi Beta Kappa.

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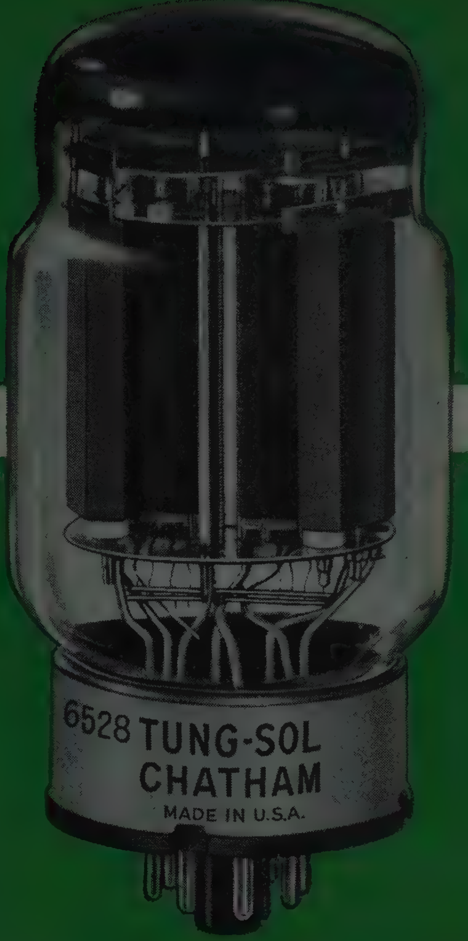
*(Continued on page 72A)*



**6528** medium mu, high current, twin power triode for series regulator service!

# Volume output makes Tung-Sol/Chatham 6528 available for widespread use!

Enthusiastic acceptance of the 6528 Twin Power Triode forced rapid expansion of production quotas, in turn resulting in lower manufacturing costs. These savings are reflected in lower prices to the user making Type 6528 economically practical for a vast number of new industrial and military applications.

Type 6528 requires fewer passing tube sections . . . permits lower range control circuits . . . and combines low internal tube drop with top control sensitivity — a definite advantage over previous series regulators. Also, 6528 triodes may be used in parallel or separately. This simplifies circuitry . . . saves space.

**DESIGN FEATURES OF TUNG-SOL/CHATHAM TYPE 6528!**

1. Hard glass envelope permits full out-gassing . . . takes higher temperatures without gas evolution . . . increases thermal shock resistance.
2. Zirconium-coated graphite anodes assure excellent gettering. Graphite virtually unaffected by heat.
3. Oversize cathodes provide adequate emission reserve . . . eliminate standby deterioration.
4. Extra-rugged grids. Sturdy chrome-copper side rods support gold-plated molybdenum lateral wires.
5. Overall ruggedness. Metal snubbers and ceramic insulators support mount. Heavy button-stem has rigid support leads.

Tung-Sol Electric Inc. specializes in special-purpose tube development . . . can match any design requirement you have. For full data on Type 6528 . . . to fill any power tube socket . . . contact: Tung-Sol Electric Inc., Newark 4, N. J. Commercial Engineering Offices: Bloomfield and Livingston, N. J.; Culver City, Calif.; Melrose Park, Ill.

**TYPE 6528 RATINGS**

| | |
|---|---|
| Max. plate dissipation per tube | 60 watts |
| Max. plate dissipation per section | 30 watts |
| Max. steady plate current per section | 300 ma. |
| Max. plate voltage | 400 volts |
| Max. heater cathode voltage | 300 volts |
| Amplification factor* | 9 |
| Transconductance per section* | 37,000 μmhos |

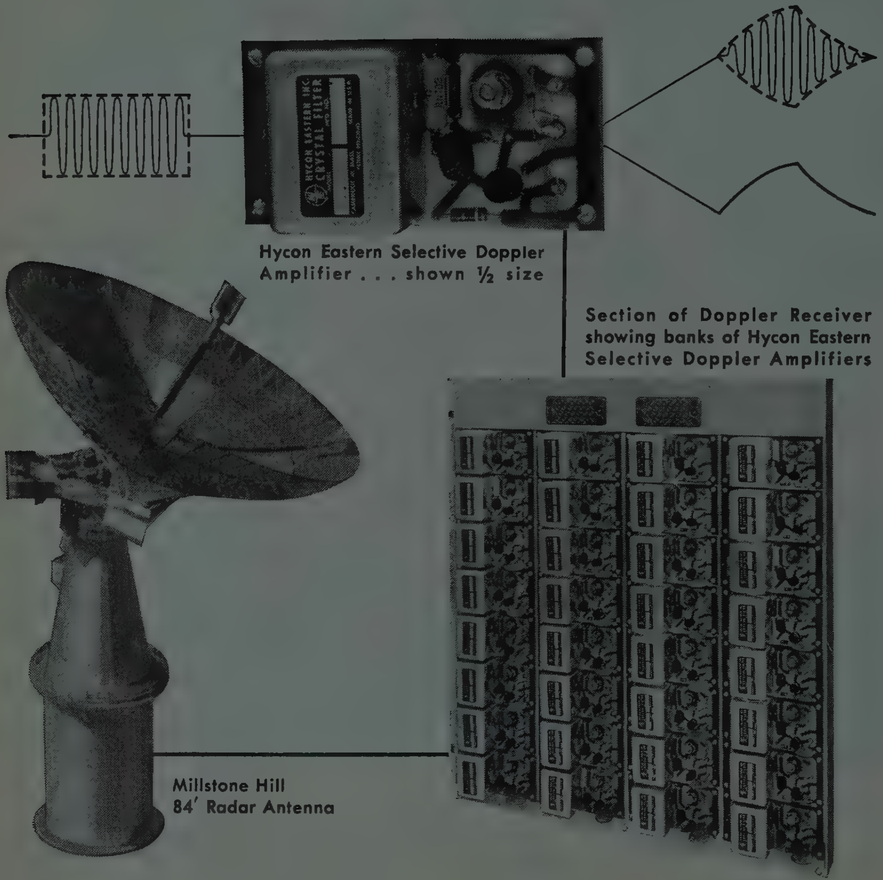
**Average characteristics at* $E_b = 100v$, $E_c = -4v$, $I_b = 185$ *ma.*

**ts TUNG-SOL®**

**FIRST 1,040 Mile**

**Pulse Doppler Radar uses**

**HYCON EASTERN CRYSTAL FILTERS**



Hycon Eastern Selective Doppler Amplifier . . . shown ½ size

Section of Doppler Receiver showing banks of Hycon Eastern Selective Doppler Amplifiers

Millstone Hill 84′ Radar Antenna

The problems in long range radar for today's ballistic missile defense systems require solutions that are unique yet reliable. Meeting these criteria is the Lincoln Laboratory's "Millstone Hill System". Working closely with Lincoln Laboratory on the transient response problems, Hycon Eastern provided "comb set" crystal filters and associated circuitry forming complete networks termed Selective Doppler Amplifiers.

Hycon Eastern offers a unique customer service by assuming total responsibility for exact pulse output. All crystal filters are tested and aligned under simulated operating conditions, using a pulsed input. Transistor amplification, active impedance transformation, and detector circuitry are provided for complete compatibility with the total system. These integrated units are delivered ready for immediate use.

Hycon Eastern is presently supplying crystal filter banks for airborne intercept, bomber defense, shipborne and land based detection and tracking systems. Write for Crystal Filter Bulletin.

**HYCON EASTERN, INC.**

75 Cambridge Parkway Dept. B Cambridge 42, Mass.

## IRE People

*(Continued from page 70A)*

**Walter P. Dyke** (M'56), director of Linfield Research Institute, McMinnville, Ore., received the 1958 Electronic Achievement Award of the IRE Seventh Region at the All-Industry Luncheon of WESCON. The award is given annually as recognition for outstanding contributions to electronic activities in the Region, which includes nine western states.

Dr. Dyke, who is also president of Field Emission Corporation, was cited "for his contributions to education and for his invention and engineering development in field-emission cathodes."

He was born in Forest Grove, Ore., on December 9, 1914. In 1938 he graduated from Linfield College, and in 1946 received the Ph.D. degree from the University of Washington. His early employment was in the banking field in Oregon.

During World War II, as a staff member at M.I.T., he performed radar research for military applications, for which he was awarded the Presidential Certificate of Merit. In 1946 he became head of the Physics Department of Linfield College and director of research at Linfield Research Institute. He was named Linfield's director in 1955.

He is a member of Sigma Xi, Sigma Phi Sigma, the American Association of Physics Teachers, and the American Physical Society.

*(Continued on page 74A)*

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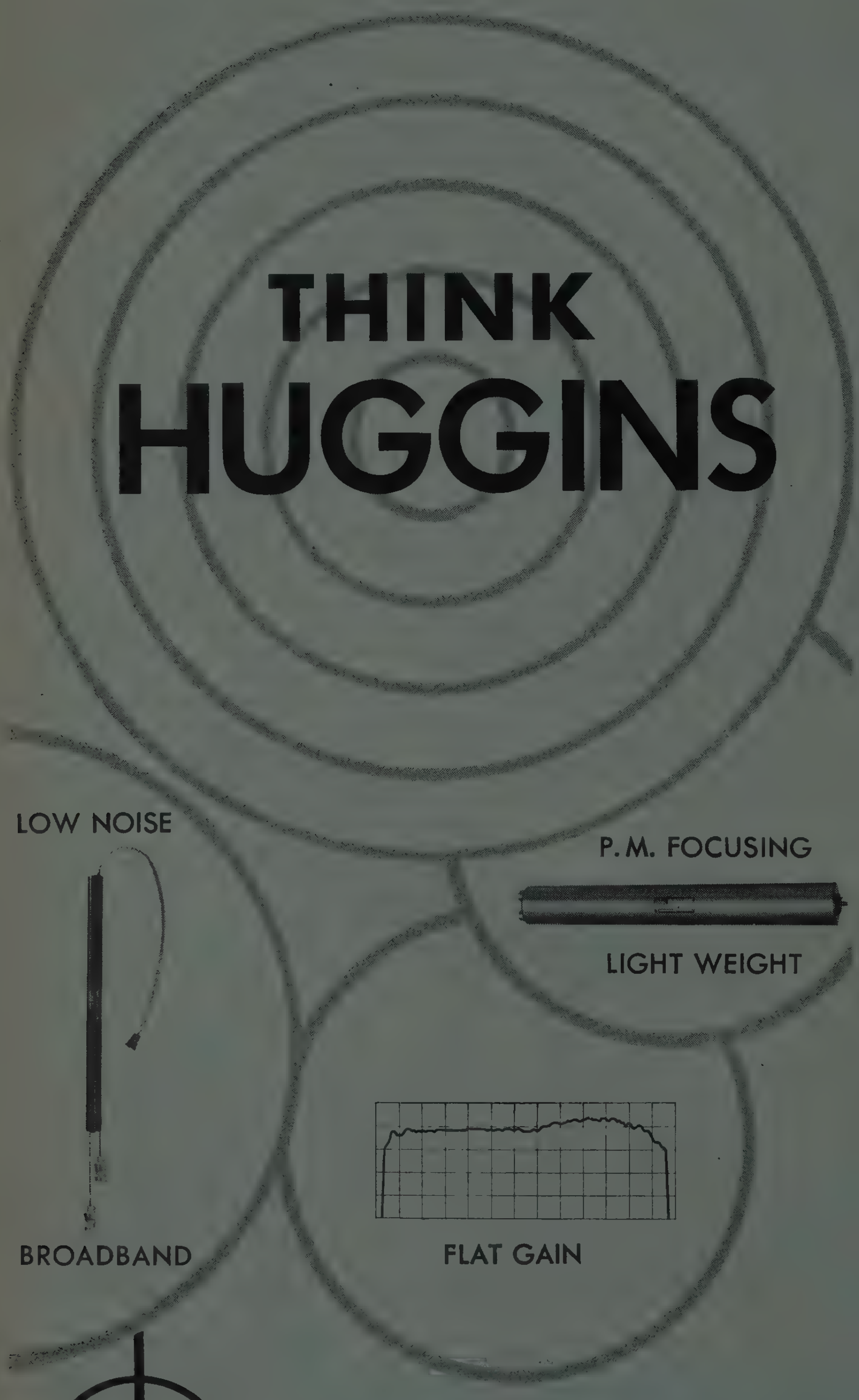

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(Continued from page 72A)

**Vern Landis, Jr.** (M'54), sales manager of Tamar Electronics, Inc., Los Angeles, Calif., has been appointed corporate general manager.

V. Landis, Jr.

He had studied electronic engineering at the University of Minnesota and Colorado A&M. Prior to joining Tamar's executive staff last year, for five years he supervised the Douglas Aircraft Company's antenna research and development laboratories at Long Beach, Calif. An acknowledged specialist in radio frequency transmission systems, particularly in the field of military electronic countermeasures, he was associated with antenna design on the B-66, C-133, C-124, and C-74 Douglas airplanes.

His other affiliations have been with the Majestic Radio and Television Company, Chicago, Ill., as a test equipment design engineer; with McGraw Electric Company, Elgin, Ill., as quality control engineer; with Illinois Bell Telephone Company, as engineer; with Muntz TV Corporation as Rock Island branch service manager; and with the U. S. Army Signal Corps as a civilian instructor in mathematics, electricity, and magnetism. During World War II he served in the U. S. Army Signal Corps.

Mr. Landis is a member of Phi Sigma Kappa.

❖

**Herbert F. Mitchell, Jr.** (S'46–A'50–M'55), has been appointed director of the management services department of the Remington Rand Univac Division, Sperry Rand Corporation, New York. Among other scientific functions, his group will facilitate the English language approach to electronic computer systems.

Dr. Mitchell is transferring from the company's Los Angeles office, where he was director of Univac Applications, Remington Rand Univac Division. He joined the Eckert-Mauchly division of Remington Rand at Philadelphia in 1949, where he was director of the company's Computational Analysis Laboratory.

He holds the B.S. degree in electrical engineering from George Washington University, and the Master's degree in engineering science (electronics) from Harvard University. He received the Ph.D. degree in numerical analysis from Harvard in 1948, and then joined the faculty of Webb Institute of Naval Architecture as a professor of engineering.

Entering the army as a captain in 1941, he worked on antiaircraft artillery electronics in the United States and Hawaii. He was discharged as a colonel in 1946.

Dr. Mitchell is a Fellow of the American Association for the Advancement of

(Continued on page 76A)

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# TYPE 543

# DC-to-30 MC OSCILLOSCOPE

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| 430-AB | 4.5 cps to 520 kc | 2% | 1% | $145.00 |
| 440-A** | .001 cps to 100 kc | 1%* | 1/10%* | $550.00 |
| 440-B** | 1 cps to 1 kc | 1/20%* | 1/10% | $950.00 |

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*(Continued from page 74A)*

Science, and is a member of the American Institute of Electrical Engineering, Association for Computing Machinery, the Institute of Management Sciences, and the Society of Industrial and Applied Mathematics.

◆

**John A. Rhoads** (SM'49), veteran of 20 years' experience in electronics design and development and engineering management, has joined Packard-Bell Electronics Corporation, Los Angeles, Calif., as director of engineering in the Technical Products Division. He replaces **George J. Mueller** (SM'47), who will remain at Packard-Bell temporarily as a consultant.

J. A. Rhoads

Mr. Rhoads received two technical degrees from the University of Southern California and took graduate courses at the Stevens Institute of Technology and the University of Pennsylvania.

*(Continued on page 78A)*

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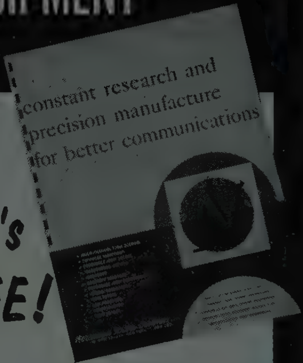
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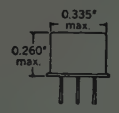
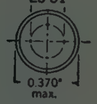
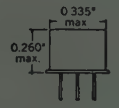
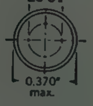
| | | Type | $I_{EO}$ or $I_{CO}$ at $V_{CB} = 20\ V_{dc}$ μA | $V_{CE}$ max. volts | $H_{FE}$† ave. | $r_{b'}$ f = 1Mc ohms | $r_c$ kilohms | Noise Figure db (max.) | $C_{ob}$ f = 100Kc ave. μμf | $f_{\alpha b}$ ave. Kc |
|---|---|---|---|---|---|---|---|---|---|---|
| TO-9  0.335" max. 0.260" max. | PNP | 2N327A | 0.005 | −40 | 15 | 1200 | 500 | 30 | 65 | 200 |
| | | 2N328A | 0.005 | −35 | 30 | 1400 | 500 | 30 | 65 | 300 |
| | | 2N329A | 0.005 | −30 | 60 | 1500 | 500 | 30 | 65 | 400 |
| | | 2N330A | 0.005 | −30 | 25 | 1300 | 500 | 15 | 65 | 250 |
| E3-51  0.370" max. | NPN | 2N619 | 0.005 | 50 | 15 | 2000 | 500 | 30 | 35 | 200 |
| | | 2N620 | 0.005 | 40 | 30 | 2500 | 500 | 30 | 35 | 350 |
| | | 2N621 | 0.005 | 30 | 60 | 2700 | 500 | 30 | 35 | 500 |
| | | 2N622 | 0.005 | 30 | 25 | 2400 | 500 | 15 | 35 | 300 |

†for PNP, $I_B = -0.1mA$; $V_{CE} = -0.5V$; for NPN, $I_B = 0.5mA$; $V_{CE} = 1.5V$

## RAYTHEON FOR SMALL SIGNAL APPLICATIONS

Temperature Range −65°C to +160°C

| | | Type | $I_{EO}$ or $I_{CO}$ at $V_{CB} = 20\ V_{dc}$ μA | $V_{CE}$ max. volts | $h_{fe}$* ave. | $h_{ie}$* max. ohms | $h_{oe}$* max. μmhos | Noise* Figure db | $C_{ob}$ f = 100Kc ave. μμf | $f_{\alpha b}$ ave. Kc |
|---|---|---|---|---|---|---|---|---|---|---|
| TO-9  0.335" max. 0.260" max. | PNP | 2N1034 | 0.005 | −40 | 15 | 3000 | 70 | 30 | 65 | 200 |
| | | 2N1035 | 0.005 | −35 | 30 | 3000 | 85 | 30 | 65 | 300 |
| | | 2N1036 | 0.005 | −30 | 60 | 3000 | 100 | 30 | 65 | 400 |
| | | 2N1037 | 0.005 | −35 | 30 | 3000 | 85 | 15 | 65 | 250 |
| E3-51  0.370" max. | NPN | 2N1074 | 0.005 | 50 | 15 | 3500 | 70 | 30 | 35 | 200 |
| | | 2N1075 | 0.005 | 40 | 30 | 3500 | 85 | 30 | 35 | 350 |
| | | 2N1076 | 0.005 | 30 | 60 | 3500 | 100 | 30 | 35 | 500 |
| | | 2N1077 | 0.005 | 30 | 25 | 3500 | 85 | 15 | 35 | 300 |

*$V_C = 5V$; $I_E = 3mA$

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(Continued from page 76A)

His career began in the late thirties when he was a design engineer in the government transmitter section of RCA. Since then he has served in important posts with a number of Los Angeles electronic companies. He has been chief engineer of Air Associates, Inc., assistant chief engineer of Bendix Aviation Corporation, director of engineering at Hoffman Electronics Corporation and division manager at Hycon Electronics. Prior to joining Packard-Bell he was associated with Collins Corporation in Burbank, Calif. His background also includes design and project supervision in the development of a wide range of electronic equipment and systems for the Civil Aeronautics Administration, the U. S. Army Signal Corps, the U. S. Navy Bureau of Ships, and the U. S. Air Force.

Mr. Rhoads is a registered professional engineer in California.

◆

The General Electric Company has announced the election of **George F. Metcalf** (A'28–M'38–F'42) to the new office of regional vice-president, Washington defense activities. Mr. Metcalf will represent G.E.'s executive office on defense matters, and will appraise the company's effectiveness in fulfilling its defense obligations. His former position was general manager of the missile and ordnance systems department in Philadelphia.

◆

**Maurice H. Kebby** (S'46–A'48–M'55) has been promoted to Product Development Manager in Lenkurt Electric Company's Commercial Products Division, San Carlos, Calif. He will direct development, engineering, and quality control of communications systems and components. He had previously directed development of Lenkurt carrier and microwave radio systems as a development engineer.

M. H. Kebby

Mr. Kebby attended San Jose State College and Stanford University, where he received the B.S. degree in electrical engineering. He was on active duty as a lieutenant in the Navy for five years. Before joining Lenkurt in 1951, he was employed with Mackay Radio and Telegraph Company.

◆

(Continued on page 80A)

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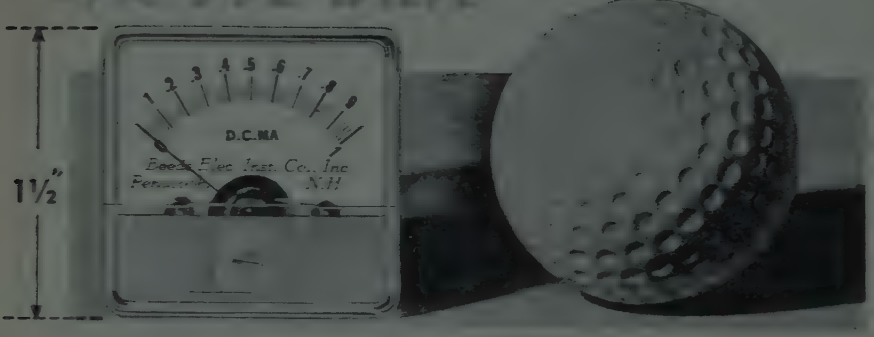

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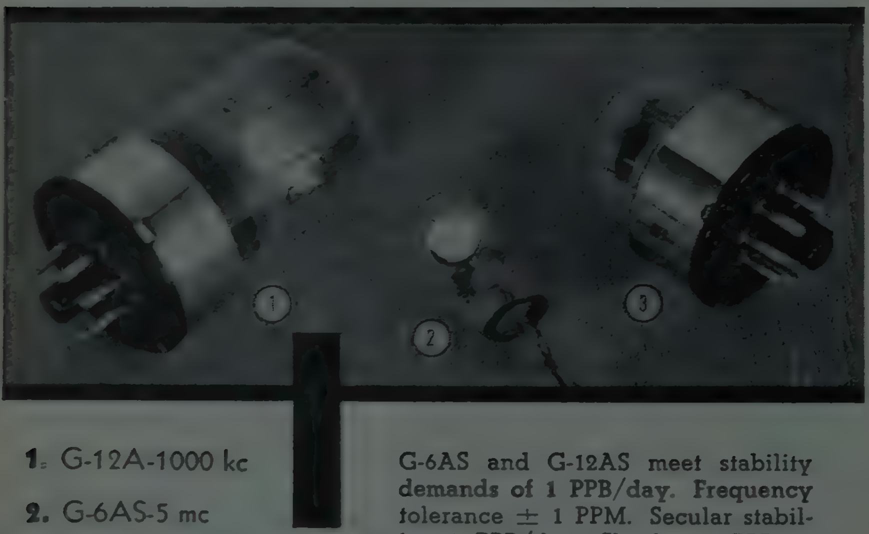

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## IRE People

*(Continued from page 78A)*

**Roland H. Joe** (S'49–A'51–M'57), has joined the Control Systems Division, The Ramo-Wooldridge Corporation, Los Angeles, Calif. He was previously associated with Topp Manufacturing in test specification and equipment design, and has also had experience in environmental engineering, fire control systems, and antenna analysis.

A native of San Bernardino, Calif., he received the B.S.E.E. degree in 1951 from the University of California at Berkeley.

◆

Appointment of **Robert A. Marshall** (A'56) as general sales manager of Federal Electric Corporation of Paramus, N. J., service organization of International Telephone and Telegraph Corporation, has been announced by Francis H. Lanahan, FEC President. Among other projects, FEC maintains and operates the DEW Line, a 3000-mile radar chain across the northernmost reaches of North America, and the White Alice project, an integrated civilian and military communications system in Alaska.

A native of Chicago, Ill., Mr. Marshall joined FEC in 1953 as an electronics field engineer. In 1956 he was named manager of FEC's Plans and Projects Department, and a year later he was appointed manager of the APOGEE Project, a plan involving the equipping and servicing of automatic teletypewriter systems internationally. He became assistant director of customer relations earlier this year.

He attended Northwestern University and also took courses at the U. S. Maritime Radio Service School and the U. S. Maritime Radar and Electronics School. During World War II he served as a radio officer in the U. S. Merchant Marine.

Before joining FEC, Mr. Marshall served as a field engineer for Radio Corporation of America's service company at Gloucester, N. J

◆

During the Tenth Annual presentation of awards to employees of the National Bureau of Standards, **F. W. Brown** (A'54), Director of the Boulder Laboratories, received the 1957 Honor Award of the Department of Commerce. A plaque was presented to Dr. Brown at ceremonies in Boulder, Colo., by **Dr. Allen V. Astin** (SM'50–F'54), Director of the National Bureau of Standards.

**Herman V. Cottony** (M'45–SM'51) was one of five employees who received pins commemorating their twenty years of service at NBS.

**1959**
**Radio Engineering Show**
**March 23-26, 1959**
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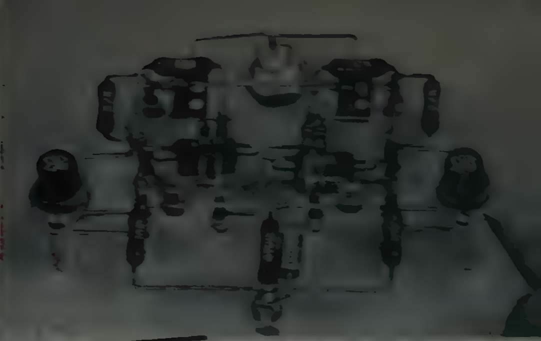

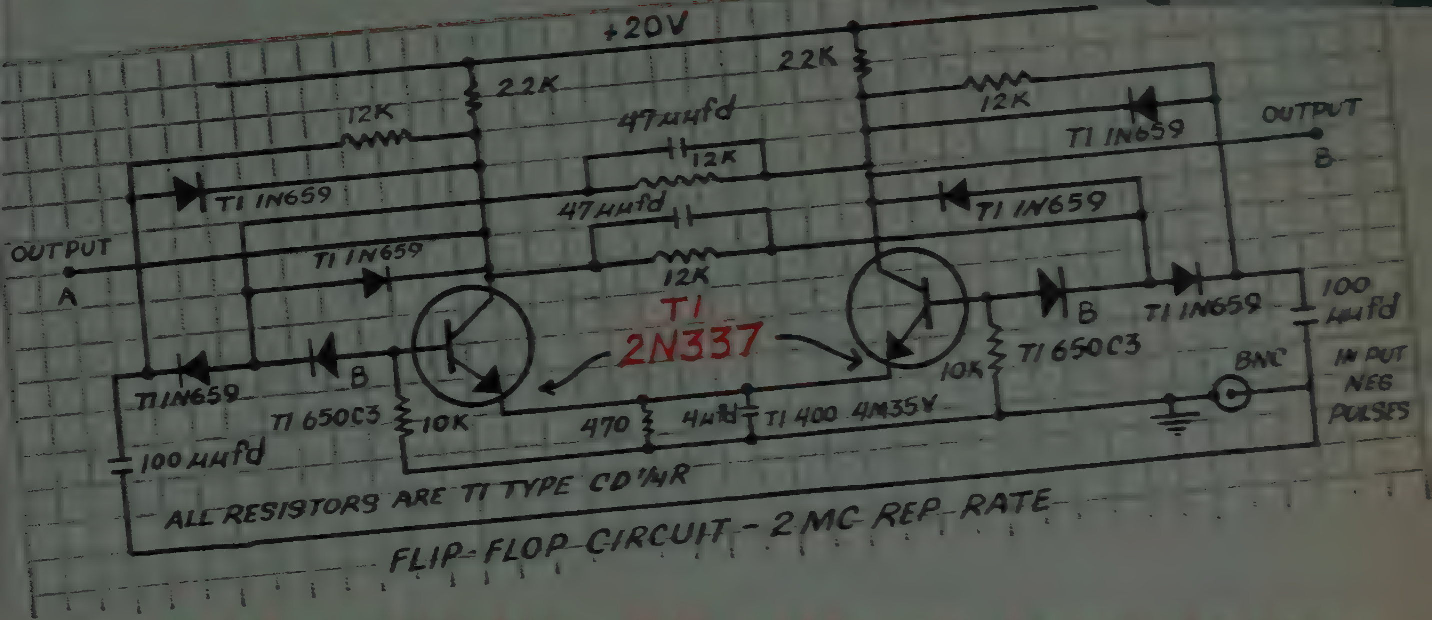
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22K
22K
12K
12K
47μμfd
12K
47μμfd
12K
TI IN659
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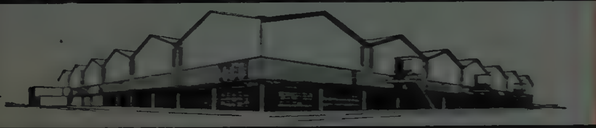
Consider TI's guaranteed specifications when you select semiconductor devices for your next transistor circuit.

**design characteristics at 25° C ambient** (except where advanced temperatures are indicated)

| | | test conditions | | 2N337 min | 2N337 design center | 2N337 max | 2N338 min | 2N338 design center | 2N338 max | unit |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_{CBO}$ | Collector Cutoff Current | $V_{CB} = 20V$ | $I_E = 0$ | — | — | 1 | — | — | 1 | μA |
| | at 150°C | $V_{CB} = 20V$ | $I_E = 0$ | — | — | 100 | — | — | 100 | μA |
| $BV_{CBO}$ | Breakdown Voltage | $I_{CB} = 50\mu A$ | $I_E = 0$ | 45 | — | — | 45 | — | — | V |
| $BV_{EBO}$ | Breakdown Voltage | $I_{EB} = 50\mu A$ | $I_C = 0$ | 1 | — | — | 1 | — | — | V |
| $h_{ib}$ | Input Impedance | $V_{CB} = 20V$ | $I_E = -1mA$ | 30 | 50 | 80 | 30 | 50 | 80 | Ohm |
| $h_{ob}$ | Output Admittance | $V_{CB} = 20V$ | $I_E = -1mA$ | — | 0.2 | 1 | — | 0.2 | 1 | μmho |
| $h_{rb}$ | Feedback Voltage Ratio | $V_{CB} = 20V$ | $I_E = -1mA$ | — | 200 | 2000 | — | 300 | 2000 | $X10^{-6}$ |
| $h_{fb}$ | Current Transfer Ratio | $V_{CB} = 20V$ | $I_E = -1mA$ | 0.95 | 0.985 | — | 0.975 | 0.99 | — | — |
| $h_{FE}$ | DC Beta | $V_{CE} = 5V$ | $I_C = 10mA$ | 20 | 35 | 55 | 45 | 80 | 150 | — |
| $f_{\alpha b}$ | Frequency Cutoff | $V_{CB} = 20V$ | $I_E = -1mA$ | 10 | 20 | — | 20 | 30 | — | mc |
| $C_{ob}$ | Collector Capacitance* | $V_{CB} = 20V$ | $I_E = -1mA$ | — | 1.2 | 3 | — | 1.2 | 3 | μμf |
| $R_{cs}$ | Saturation Resistance† | $I_B$ ‡ | $I_C = 10mA$ | — | 75 | 150 | — | 75 | 150 | Ohm |
| $h_{fe}$ | Current Transfer Ratio | $V_{CB} = 20V$ | $I_E = -1mA, f = 2.5mc$ | 14 | 22 | — | 20 | 24 | — | db |
| $t_r$ | Rise time§ | | | — | 0.05 | — | — | 0.06 | — | μsec |
| $t_s$ | Storage Time | | | — | 0.02 | — | — | 0.02 | — | μsec |
| $t_f$ | Fall time | | | — | 0.08 | — | — | 0.14 | — | μsec |

* Measured at 1 mc † Common Emitter ‡ $I_B$ = 1mA for 2N337, 0.5mA for 2N338 § Includes delay time ($t_d$)



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Write today for complete information, on models currently in production—or let us quote, without obligation, on special molded encapsulated transformers which we can manufacture to meet your most rigid requirements.

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**(Reduced Inspection—Quality Assurance Plan)** Your own incoming inspection and field service requirements are reduced to a minimum when you specify Triad. All Triad Transformers are manufactured under this Signal Corps approved plan for quality assurance. RIQAP is awarded only to those companies who continue to maintain Signal Corps standards.

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## Professional Group Meetings

### AUDIO

Baltimore—May 22

"The Dynamic Loudspeaker—Can We Improve It?" Saul J. White, Racon Electric Co.

Boston—May 15

"Practical Stereophonic Phonograph Records," R. E. Warn and E. A. Dickinson, Westrex Co.

### COMMUNICATIONS SYSTEMS

San Francisco—June 10

"Practical Application of Scatter Communications in Alaska," Robert B. Stecker, Western Electric Co., N.Y.

### COMPONENT PARTS

Baltimore—June 24

"Applications and Limitations of Magnetic Modulators," Reuben Lee, Westinghouse Electronics Div.

Los Angeles—June 16

Joint Meeting with Professional Groups: Reliability and Quality Control and Electron Devices.

Los Angeles—June 30

"Discussion of Transformer for Airborne Equipment," H. N. Ford, Hughes Aircraft Co.

### ELECTRON DEVICES

Los Angeles—June 16

"The Measures of Reliability," David Cowan, Hughes Products; "Semiconductor Diode Reliability—Evaluation and Control," Arthur Feldon, Pacific Semiconductors, Inc.

### ELECTRONIC COMPUTERS

Pittsburgh—February 12

"The Computer for General Accounting Calculations," Donald L. Trasky, Crucible Steel Co.; "The Computer for Statistical and Operations Research Type Operations," Duncan McCune, Jones and Laughlin Steel Corp.

### ENGINEERING WRITING AND SPEECH

Los Angeles—June 18

"Communications is our Business," Admiral Charles F. Horne (USN Ret.), Convair Division, General Dynamics Corp.; "Improving Oral Presentations," Dr. Ralph F. Richardson, U.C.L.A.

### MILITARY ELECTRONICS

Fort Wayne—May 1

"Nuclear Radiation Effects on Electronic Equipment," James Frazier, The General Electric Co.

*(Continued on page 84A)*

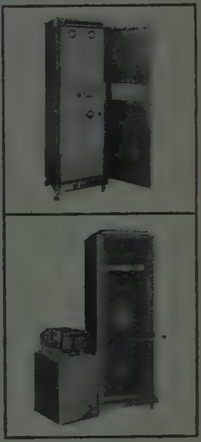
# HOW SCATE SOLVES 2 BASIC PROBLEMS

## in testing electronic systems

Many complex electronic systems—missile guidance is a good example—may require testing that takes days by conventional methods. Yet the end function of such a system may last only a few minutes—**even seconds.**

Other systems, though less complex, must be tested in such large numbers that adequate personnel are frequently unavailable to perform tests by conventional means.

The SCATE system of automatic test equipment can solve **both** problems. It provides **self-checking** automatic testing which is **fast, flexible** and **foolproof.**



The system evaluates all important parameters of equipment under test, including:

1. RF sensitivity, center frequency, band width, power output, noise figure.
2. Audio frequency gain, band width, power output.
3. Video pulse circuitry, including pulse decoding, logic, digital comparison, pulse delays.
4. Voltage levels, DC and AC.
5. Servo response.
6. Mechanical response.

Stromberg-Carlson has standing designs for all the standard components which go into a SCATE system, and is fully experienced in designing custom components which may be required in any test system.

Complete details on the SCATE system and other Stromberg-Carlson automatic test equipment are available on request.

*** Missile guidance system can be tested automatically by the SCATE system.**

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MOST COMPACT • SIMPLEST • MOST ECONOMICAL
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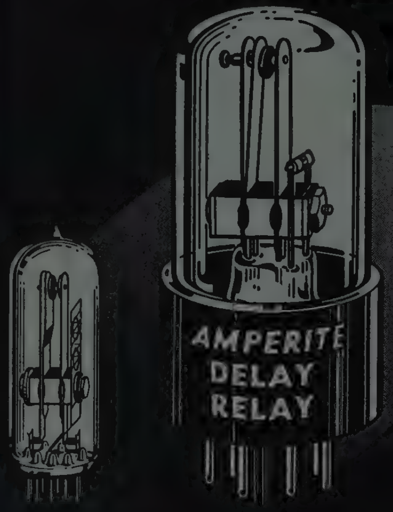


Thermostatic
DELAY RELAYS
2 to 180 Seconds

Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.

**Hermetically sealed.** Not affected by altitude, moisture, or climate changes.

**SPST only**—normally open or closed.

Compensated for ambient temperature changes from —55° to + 70° C. Heaters consume approximately 2 W. and may be operated continuously. The units are **rugged, explosion-proof, long-lived, and—inexpensive!**

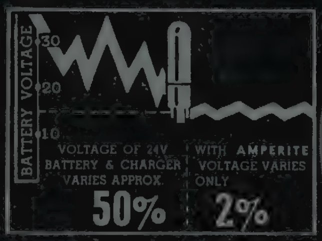
TYPES: Standard Radio Octal and 9-Pin Miniature . . . . List Price, $4.00, Standard Delays

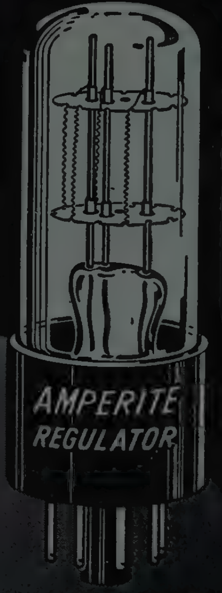
Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

*PROBLEM? Send for Bulletin No. TR-81*

BALLAST REGULATORS

Amperite Regulators are designed to keep the current in a circuit **automatically regulated** at a definite value (for example, 0.5 amp.) . . For currents of 60 ma. to 5 amps. Operate on A.C., D.C., or Pulsating Current.





**Hermetically sealed,** they are not affected by changes in altitude, ambient temperature (—55° to + 90° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . . . . . . List Price, $3.00.

*Write for 4-page Technical Bulletin No. AB-51*

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In Canada: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto 10

# Professional Group Meetings

(*Continued from page 82A*)

Fort Wayne—June 5

"Exploring the Universe with Radio," Dr. John W. Findlay, National Radio Astronomy Observatory.

## TELEMETRY AND REMOTE CONTROL

San Francisco—January 21

"A Transistor-Driven Magnetic-Core Memory Using Non-Coincident Current Techniques," Robert L. Koppel, Lockheed Missile Systems Div.; "High-Capacity, High-Speed Digital Telemetry System," Robert L. Sink, Consolidated Electrodynamics Corp.

San Francisco—February 18

"Transistorized Scanning and Control Equipment with Very Long Life for Industrial Use," Laurence Moore, Moore Associates, Inc.; "Characteristics of Mercury-Jet Commutators," William Snyder, Detroit Controls.

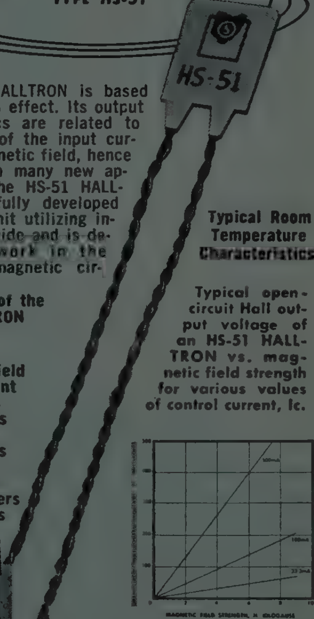
(*Continued on page 86A*)

NEW
SEMICONDUCTOR
DEVICE

Halltron
TYPE HS-51

The HS-51 HALLTRON is based upon the Hall effect. Its output characteristics are related to the product of the input current and magnetic field, hence are useful in many new applications. The HS-51 HALLTRON is a fully developed production unit utilizing indium antimonide and is designed to work in the customer's magnetic circuit.

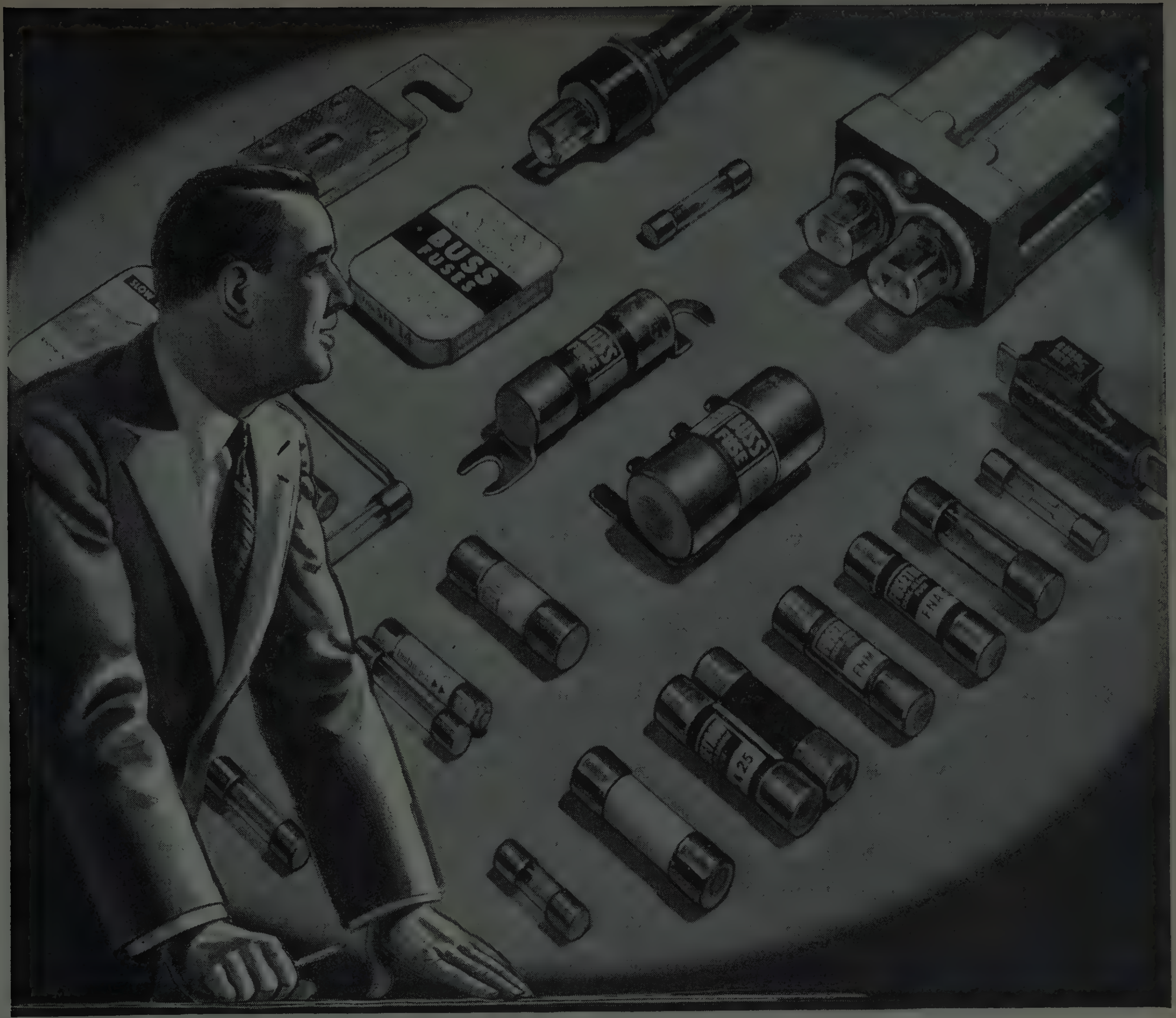
**Applications of the HS-51 HALLTRON**
- DC to AC converters
- Magnetic field measurement
- Computer applications
- Control applications
- Gyrators
- Circulators
- Power meters
- Transducers



Typical Room Temperature Characteristics

Typical open-circuit Hall output voltage of an HS-51 HALLTRON vs. magnetic field strength for various values of control current, Ic.

OHIO SEMICONDUCTORS, INC.
1035 W. THIRD AVENUE, COLUMBUS 8, OHIO



# *BUSS Fuses provide* Maximum Protection *against damage due to electrical faults*

When an electrical fault occurs, BUSS fuses quickly clear the circuit. By preventing useless damage, BUSS fuses help to get your equipment back in operation sooner. Users of your equipment are safeguarded against the expense of unnecessary repair bills.

BUSS fuse dependability also prevents needless blows that 'knock' equipment out-of-service without cause. Users are protected against irritating and often costly shutdowns due to faulty fuses blowing when trouble does not exist.

**Electronic Testing Assures Dependability in BUSS Fuses**

Every BUSS fuse is tested in a sensitive electronic device that automatically rejects any fuse not correctly calibrated, properly constructed and right in all physical dimensions.

By specifying BUSS fuses, you are providing the finest electrical protection possible, — and you are helping to safeguard the reputation of your product for quality and reliability. To meet your needs, the BUSS fuse line is most complete.

**If you have an unusual or difficult protection problem** . . . let the BUSS fuse engineers work with you and save you engineering time. If possible, they will suggest a fuse already available in local wholesalers' stocks, so that your device can easily be serviced.

For more information on BUSS and FUSETRON Small Dimension fuses and fuseholders, write for bulletin SFB.

Bussmann Mfg. Division McGraw-Edison Co., University at Jefferson, St. Louis 7, Mo.

*BUSS fuses are made to protect – not to blow, needlessly*

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## Professional Group Meetings

*(Continued from page 84A)*

San Francisco—March 18

"P.C.M.—Fact or Fiction," Peter Dietz, Radiation, Inc.; "Technical Factors Influencing Choice Between Pulse Code and Frequency Code Data Transmission System," Earl A. Ragland, Bendix Aviation Corp. (Pacific Div.)

San Francisco—April 15

"Telemetering the Explorer Satellite," Lee Randolph, Calif. Inst. Tech.

San Francisco—May 20

"Automatic Production Testing of Telemetering FM Subcarrier Oscillators," Robert A. Andersen, DYNAC, Inc.

## Membership

**The following transfers and admissions have been approved and are now effective:**

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Blair, C. R., Silver Spring, Md.
Bowles, L. T., Jr., Owensboro, Ky.
Briskin, H. B., Syosset, L. I., N. Y.
Byrd, D. J. P., Los Angeles, Calif.
Dickman, A., Plainview, L. I., N. Y.
Dulmage, H. B., Stouffville, Ont., Canada
Falco, M. F., South Bend, Ind.
Headstrom, R. L., Midwest City, Okla.
Healy, D. W., Jr., Cazenovia, N. Y.
Jones, W. V., Jr., South Bend, Ind.
Katz, S., Philadelphia, Pa.
Krepps, J. E., Jr., Bloomington, Ind.
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Morrison, D. O., Mt. Clemens, Mich.
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Cochran, U. E., Idaho Falls, Idaho
Cole, E. M., Sr., Los Angeles, Calif.
Coleman, H. B., Northridge, Calif.

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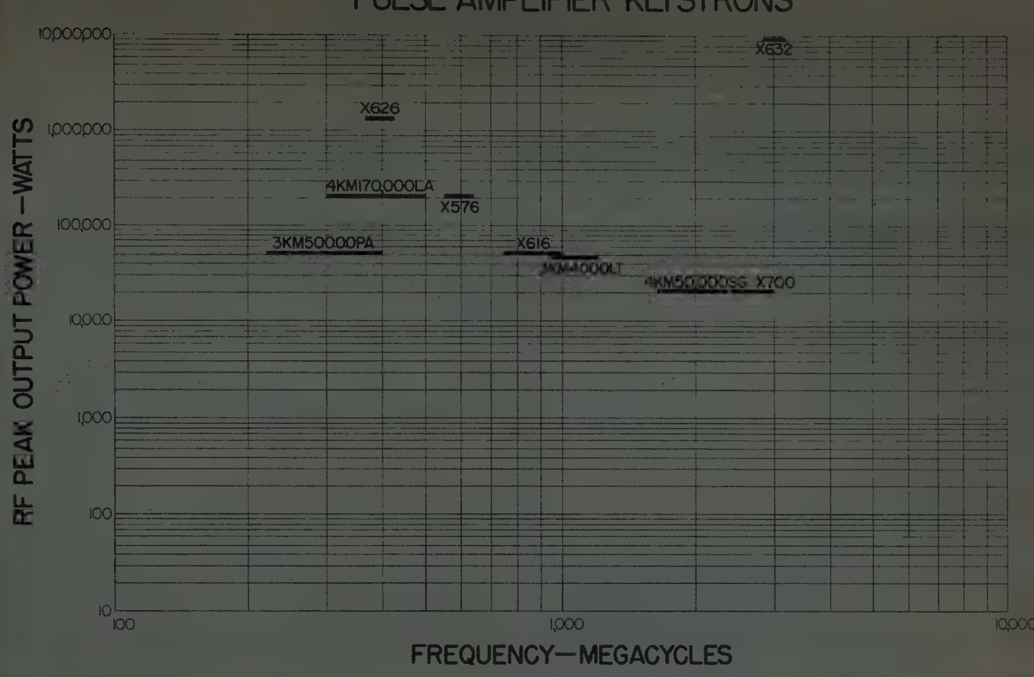
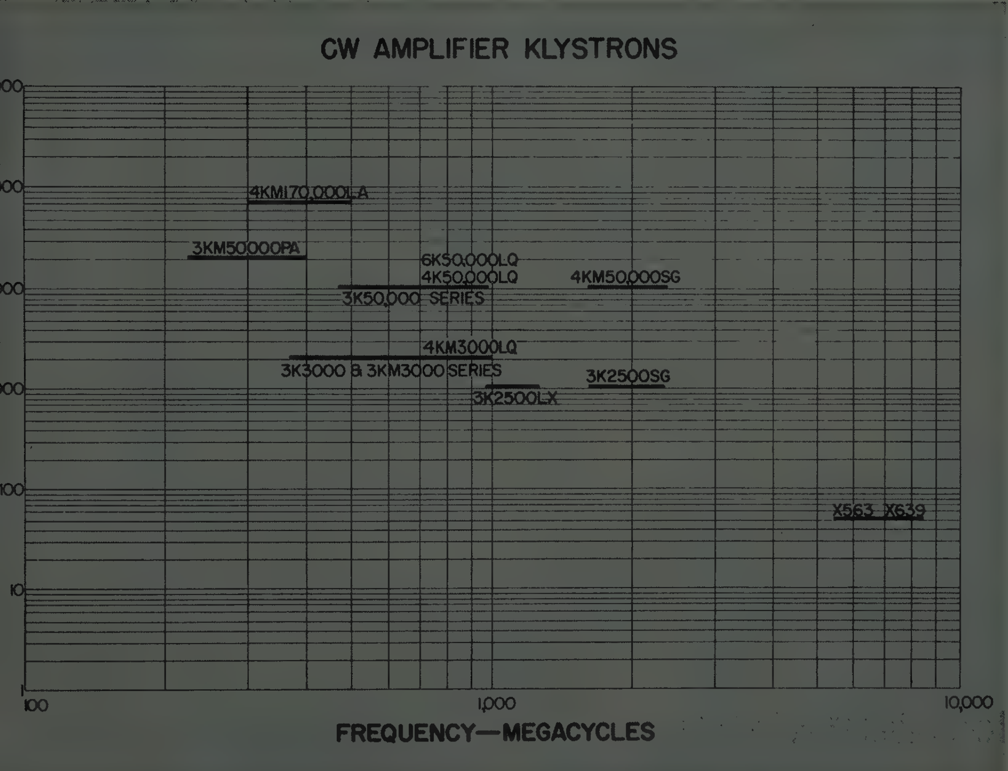


# Eimac First for Power Amplifier Klystrons

# ...Across the RF SPECTRUM



The exceptional ability of Eimac amplifie klystrons to conveniently and reliably generate high RF power at ultra-high and super high frequencies makes them ideal for use i such important aeronautical applications a high-power ground-to-air communications TACAN and other air navigational systems super-power radar for missile tracking, tropo scatter communications networks for early warning defense and other UHF microwave systems.

The broad frequency coverage and wid power range now offered by Eimac amplifie klystrons is shown in the accompanying charts Frequency coverage extends into the SH range, and multi-megawatt pulse outpu powers are available.

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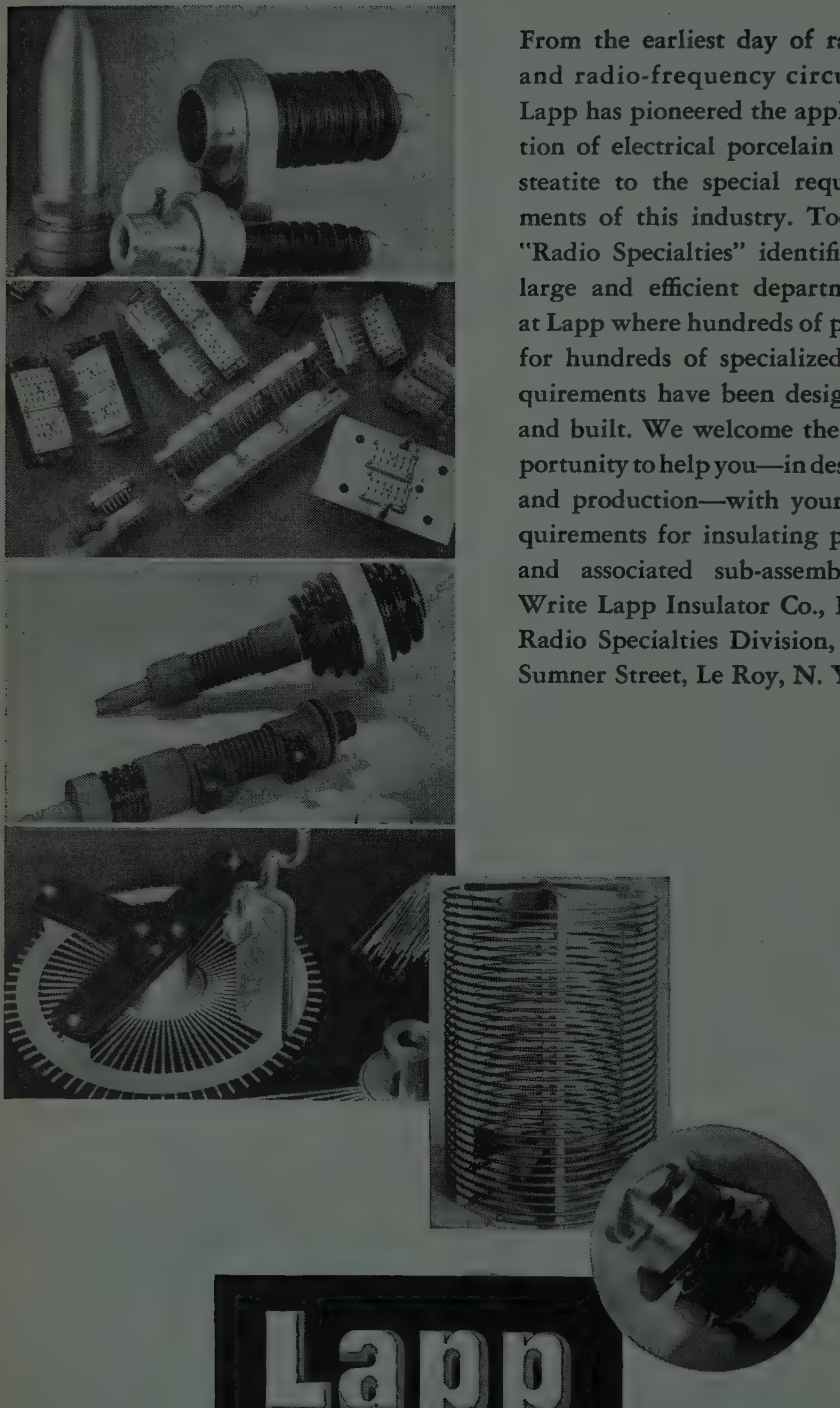

Lapp

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(Continued from page 86A)

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Gottlieb, D. C., Minneapolis, Minn.
Green, P. S., Rego Park, L. I., N. Y.
Grieve, W. R., Whittier, Calif.
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(Continued on page 90A)

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**HIGH PRECISION, DIRECT READING METERS (0.015%)**

Series 555 to 579 consists of 30 different types covering from 0.925 to 39.0 KMC/S. Representing highest state of the art, these frequency meters fully qualify as transfer or secondary standards for exacting laboratory or production service. Features include: hermetically sealed invar cavity, temperature-compensation, high Q, optimum cavity geometry, high conductivity plating.

**PRECISION HETERODYNE FREQUENCY METER (0.002%)**

Type 504, for 100 to 10,000 MC/S with accuracy of 0.002% at crystal check points every 5 MC/S and 0.03% or better between check points. Automatic interpolation by unique patented spiral-scale dial. Beat indication by both external earphones and built-in CRT. Meter is self-contained and portable.

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Series 585-A to 590-A affords excellent accuracy at lowest cost from 5.1 to 10.0 KMC/S. Ideally suited for panel mounting.

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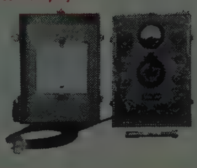
**LINE TERMINATING, HIGH PRECISION METER (±0.3 MC/S)**

Type 560, ranges 2.4 to 3.4 and 2.7 to 3.7 KMC/S. Extremely wide range of pulse average power as well as CW can be handled. Hermetically sealed cavity and temperature-compensation permit operation under conditions of adverse humidity or large temperature variations.



**CALIBRATED, PRECISION METER (±0.3 MC/S)**

Type 583-D, for 2.4 to 3.7 KMC/S. Temperature-compensation and hermetical sealing insure optimum performance under all atmospheric conditions.

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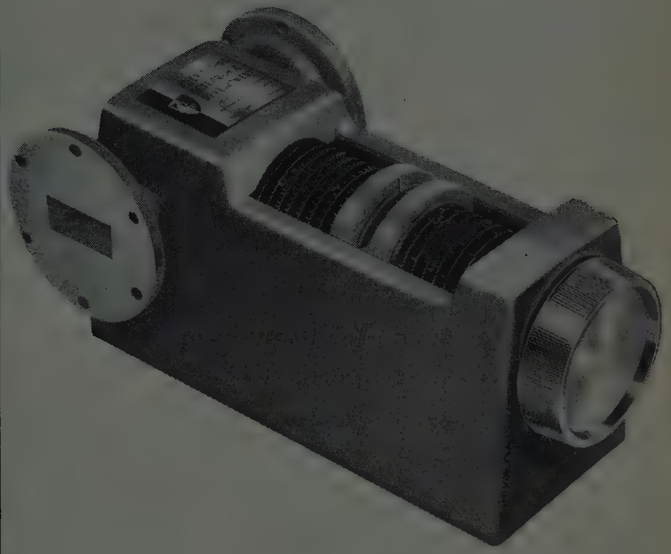
Type 587-A, covers range 250 to 1000 MC/S. Spiral drum scale 60 inches long enables precision direct reading. May also be used as a tunable narrow band filter.



Seven full waveguide bandwidths are each covered by a separate meter in this 532 series of nine reaction-coupled frequency meters, extending over the complete range from 3.95 to 40.0 KMC/S.

These frequency meters consist of a $TE_{111}$ mode cavity resonator tuned by a non-contacting plunger. Ruggedness for long trouble-free life is assured by all-metal construction. Maximum readability, resolution and accuracy to ±0.08% are the result of an optimized design distinguished by a drum type spiral scale more than 8 feet long.

*Full details of PRD* FREQUENCY METERS *and the complete PRD* PACEMAKER LINE *are contained in this new 160 page PRD Microwave Catalog, largest and most informative ever published. It is available without cost or obligation to those engaged in microwave work. Write for your copy today.*

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# FREED

## MIL-T-27A POWER, FILAMENT, PULSE & AUDIO TRANSFORMERS

FOR IMMEDIATE DELIVERY FROM STOCK

### POWER TRANSFORMERS-STANDARD

All primaries 105/115/125 v., 60 c.p.s.

| Cat. No. | Hi Volt Sec. | ct | DC Volts | DC Amps | Filament #1 Volt | Filament #1 Amp. | Filament #2 Volt | Filament #2 Amp. | MIL Case Size |
|---|---|---|---|---|---|---|---|---|---|
| MGP1 | 400 200 | √ | 185 | .070 | 6.3 5 | 2 | 6.3 | 3 | HA |
| MGP2 | 650 | √ | 260 | .070 | 6.3 5 | 2 | 6.3 | 4 | JB |
| MGP3 | 650 | √ | 245 | .150 | 6.3 | 5 | 5.0 | 3 | KB |
| MGP4 | 800 | √ | 318 | .175 | 5.0 | 3 | 6.3 | 8 | LB |
| MGP5 | 900 | √ | 345 | .250 | 5.0 | 3 | 6.3 | 8 | MB |
| MGP6 | 700 | √ | 255 | .250 | | | | | KB |
| MGP7 | 1100 | √ | 419 | .250 | | | | | LB |
| MGP8 | 1500 | √ | 640 | .250 | | | | | MB |

### FILAMENT TRANSFORMERS-STANDARD

All primaries 105/115/125 v., 60 c.p.s.

| Cat. No. | Secondary Volt | Secondary Amp | Test VRMS | MIL Case |
|---|---|---|---|---|
| MGF1 | 2.5 | 3.0 | 2,500 | EB |
| MGF2 | 2.5 | 10.0 | 2,500 | GB |
| MGF3 | 5.0 | 3.0 | 2,500 | FB |
| MGF4 | 5.0 | 10.0 | 2,500 | HB |
| MGF5 | 6.3 | 2.0 | 2,500 | FB |
| MGF6 | 6.3 | 5.0 | 2,500 | GB |
| MGF7 | 6.3 | 10.0 | 2,500 | JB |
| MGF8 | 6.3 | 20.0 | 2,500 | KB |
| MGF9 | 2.5 | 10.0 | 10,000 | JB |
| MGF10 | 5.0 | 10.0 | 10,000 | KB |

### PULSE TRANSFORMERS

| Cat. No. | Block'g. Osc. | Int. Coupl'g. | Low. Pow. Out. | Pulse Voltage Kilovolts | Pulse Duration Microseconds | Duty Rate | No. of Wdgs. | Test Volt. KVRMS | Char. Imp. Ohms |
|---|---|---|---|---|---|---|---|---|---|
| MPT1 | √ | √ | | 0.25 0.25 0.25 | 0.2-1.0 | .004 | 3 | 0.7 | 250 |
| MPT2 | √ | √ | | 0.25 0.25 | 0.2-1.0 | .004 | 2 | 0.7 | 250 |
| MPT3 | √ | √ | | 0.5 0.5 0.5 | 0.2-1.5 | .002 | 3 | 1.0 | 250 |
| MPT4 | √ | √ | | 0.5 0.5 | 0.2-1.5 | .002 | 2 | 1.0 | 250 |
| MPT5 | √ | √ | | 0.5 0.5 0.5 | 0.5-2.0 | .002 | 3 | 1.0 | 500 |
| MPT6 | [illegible] | [illegible] | [illegible] | 0.5 0.5 | 0.5-2.0 | .002 | 2 | 1.0 | 500 |
| MPT7 | √ | √ | √ | 0.7 0.7 0.7 | 0.5-1.5 | .002 | 3 | 1.5 | 200 |
| MPT8 | [illegible] | [illegible] | [illegible] | 0.7 0.7 | 0.5-1.5 | .002 | 2 | 1.5 | 200 |
| MPT9 | √ | √ | √ | 1.0 1.0 1.0 | 0.7-3.5 | .002 | 3 | 2.0 | 200 |
| MPT10 | [illegible] | [illegible] | [illegible] | 1.0 1.0 | 0.7-3.5 | .002 | 2 | 2.0 | 200 |
| MPT11 | √ | √ | √ | 1.0 1.0 1.0 | 1.0-5.0 | .002 | 3 | 2.0 | 500 |
| MPT12 | √ | √ | √ | 0.15 0.15 0.3 0.3 | 0.2-1.0 | .004 | 4 | 0.7 | 700 |

### AUDIO TRANSFORMERS

Freq. resp. 300 to 10000 cps ± 1 DB  All Case Sizes AJ

| Catalog No. | Application | Impedance Prim. Ohms | Impedance Ct. | Impedance Sec. Ohms | Impedance Ct. | DC Current Prim. Side MA | DC Current Max. Unbal. MA | Max. Level DBM |
|---|---|---|---|---|---|---|---|---|
| MGA1 | Single or P.P. Plates — to Single or P.P. Grids | 10K | | 90K Split | √ | 10 | 10 | +15 |
| MGA2 | Line to Voice Coil | 600 Split | | 4, 8, 16 | | 0 | 0 | +33 |
| MGA3 | Line to Single or P.P. Grids | 600 Split | | 135K | | 0 | 0 | +15 |
| MGA4 | Line to Line | 600 Split | | 600 Split | | 0 | 0 | +15 |
| MGA5 | Single Plate to Line | 7.6K<br>4 ET | | 600 Split | | 40 | 40 | 33 |
| MGA6 | Single Plate to Voice Coil | 7.6K<br>4 ET | | 4, 8, 16 | | 40 | 40 | 33 |
| MGA7 | Single or P.P. Plates to Line | 15K | | 600 Split | | 10 | 10 | +33 |
| MGA8 | P.P. Plates to Line | 24K | | 600 Split | | 10 | 1 | +30 |
| MGA9 | P.P. Plates to Line | 60K | | 600 Split | | 10 | 1 | +27 |

Write for further information on these units and special designs and complete line of Mil-T-27 Reactors also available from stock. Send for complete catalog

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(Continued on page 92A)

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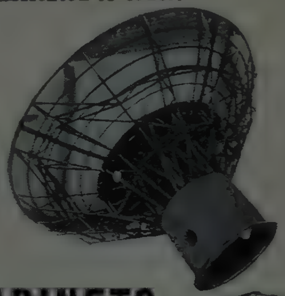

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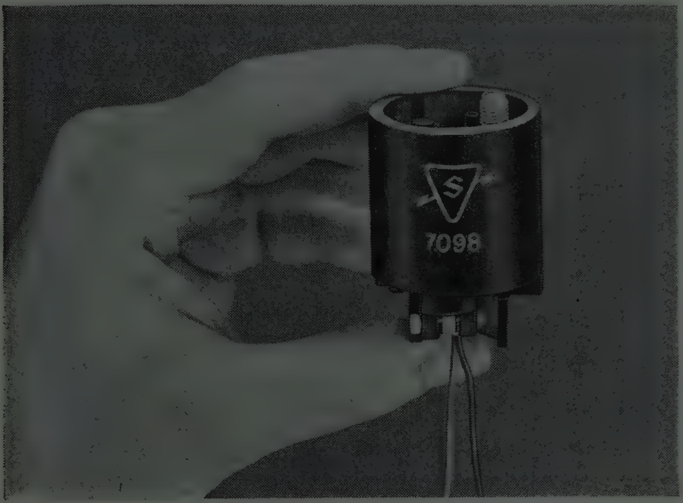
# MICROWAVE AND SPECIAL TUBE NEWS from SYLVANIA

## Six-Ounce Missile Magnetron Withstands 500 g

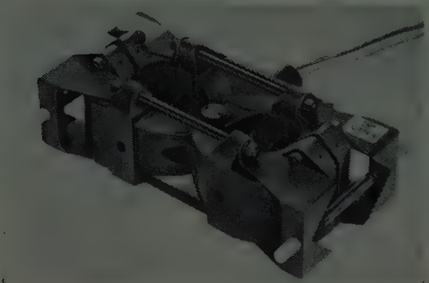


**Miniature magnetron, type 7098, for missile and beacon applications, meets extra severe environmental tests**

Palm-sized, mechanically tunable magnetron, designed to operate in the frequency range from 9300 to 9500 mc at 60 watts minimum peak power output, is now available from Sylvania. The rugged unit meets some of the military's toughest environmental requirements. Here are some of the tests that every 7098 must pass:

- Vibration of 10 to 60 cps at 0.08 inch total excursion and 60 to 2,000 cps at a constant acceleration of 15 g in each of three mutually perpendicular planes.
- Centrifuge test of 500 g acceleration.
- Linear shock test of 500 g for 1.0 ms.
- Rotation at 300 rps. without a shift in frequency greater than plus or minus 1.25 mc.

## New Ka Band Magnetrons specially designed for missile applications



**Light weight and extra ruggedness make Sylvania's new Ka band magnetrons ideal for high and low altitude pinpointing applications**

Four Ka Band magnetrons—types 6799, M 4064, M 4063 and M 4155 (ruggedized 5789), covering a power range from 20 KW to 100 KW, are now available from Sylvania. Particularly adaptable to high resolution applications, such as cloud finding, mapping and missile guidance, the three new types meet and surpass current missile vibration and shock requirements.

| Type | Peak Power Output | Weight (Approx.) |
|---|---|---|
| 6799 | 100 KW | 33 lb |
| M 4064* | 70 KW | 13 lb |
| M 4155* | 40 KW | 11 lb |
| M 4063* | 20 KW | 9 lb |

*ruggedized

## Sylvania develops and produces Backward-Wave Magnetrons

**BWM's in L, S and X Bands develop output powers as high as 600 Watts**

Sylvania, one of the pioneers in Backward-Wave Magnetron development, now has several types in pilot production and late development. The new units exhibit extremely low frequency drift and nearly flat power versus frequency characteristics. Used principally in electronic countermeasure applications for barrage jamming, BWM's offer high reliability and require less associated circuitry and equipment than other power sources.

Today, 75 percent of the engineers and technicians employed at Sylvania's extensive magnetron facilities in Williamsport, Pa. are engaged in development work. For full particulars on how these outstanding facilities can help you, contact your Sylvania representative or write Sylvania direct.

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Connections are made through Fanning Strip, on bench or anywhere apart from barrier strip, and quickly slipped into assembly.

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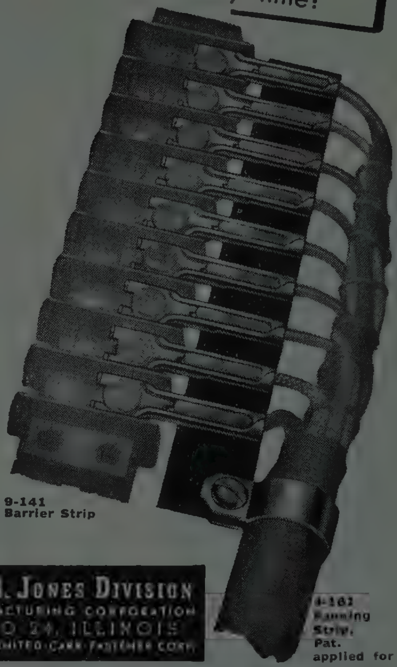

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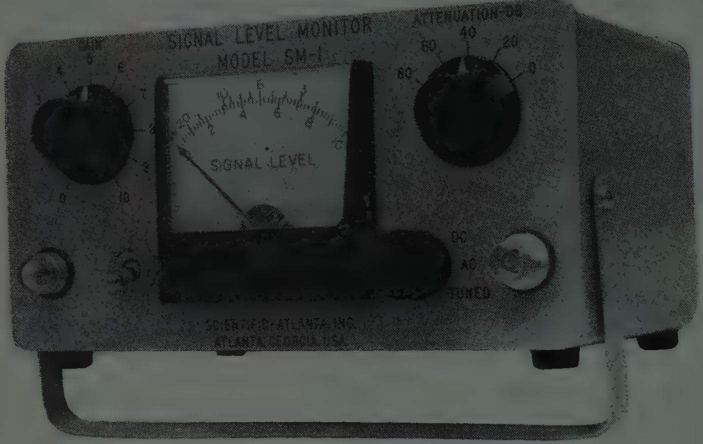

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Selover, E. E., Rome, N. Y.
Semel, D., Los Angeles, Calif.
Sessler, J. G., Fort Wayne, Ind.
Shaffer, R. A., Murray Hill, N. J.
Shapiro, J., New York, N. Y.
Sheehan, J. F., Rochester, N. Y.

(Continued on page 96A)

# Is one of these FOUR DUPLEXER TECHNIQUES right for you . . .

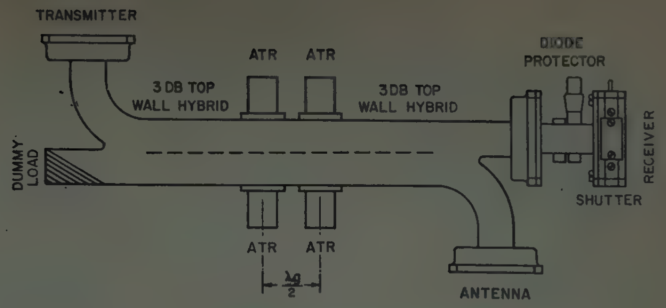
To secure optimum performance and reliability in your duplexer system you now have a choice of five basic techniques.

Microwave Associates is in a position to give you completely unbiased recommendations because we design and manufacture all types of gas tube and ferrite devices for duplexer applications.

If you have a current problem in this field our application engineering service is at your disposal.

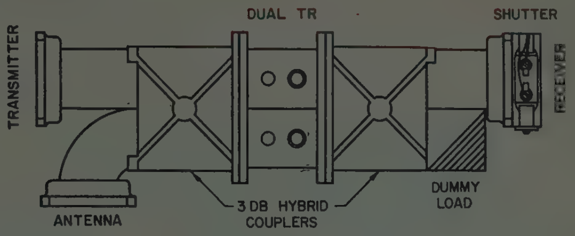
# . . . OR do you need OUR NEW FERRITE DUPLEXER?

1


TRANSMITTER
ATR
ATR
DIODE PROTECTOR
3 DB TOP WALL HYBRID
3 DB TOP WALL HYBRID
DUMMY LOAD
RECEIVER
SHUTTER
ATR
ATR
$\frac{\lambda g}{2}$
ANTENNA

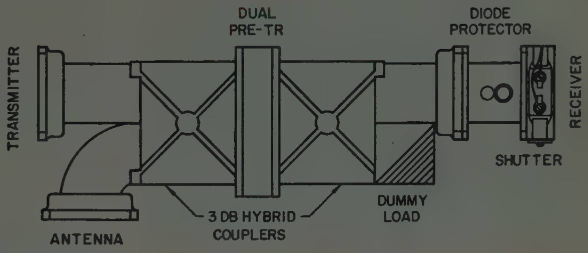
**BALANCED DUPLEXER:** **4 ATR's, DIODE PROTECTOR, SHUTTER**

2


DUAL TR
SHUTTER
TRANSMITTER
RECEIVER
DUMMY LOAD
ANTENNA
3 DB HYBRID COUPLERS

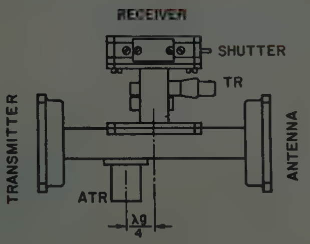
**BALANCED DUPLEXER:** **DUAL TR, SHUTTER**

3


DUAL PRE-TR
DIODE PROTECTOR
TRANSMITTER
RECEIVER
SHUTTER
DUMMY LOAD
ANTENNA
3 DB HYBRID COUPLERS

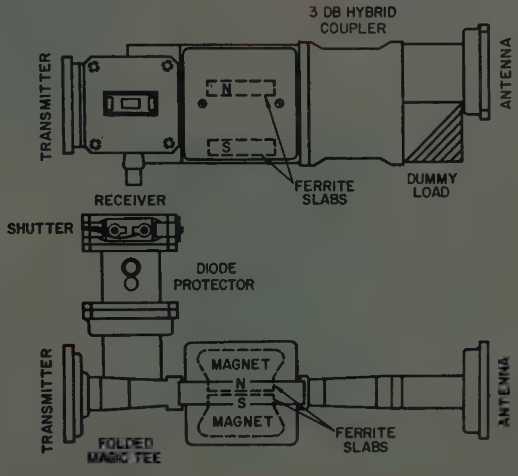
**BALANCED DUPLEXER:** **DUAL PRE-TR, DIODE PROTECTOR, SHUTTER**

4


RECEIVER
SHUTTER
TR
TRANSMITTER
ANTENNA
ATR
$\frac{\lambda g}{4}$

**BRANCHED DUPLEXER:** **ATR, TR, SHUTTER**

5


3 DB HYBRID COUPLER
TRANSMITTER
N
S
ANTENNA
FERRITE SLABS
DUMMY LOAD
RECEIVER
SHUTTER
DIODE PROTECTOR
MAGNET
N
S
MAGNET
TRANSMITTER
FOLDED MAGIC TEE
FERRITE SLABS
ANTENNA

**FERRITE DUPLEXER:** **DIODE PROTECTOR, SHUTTER**

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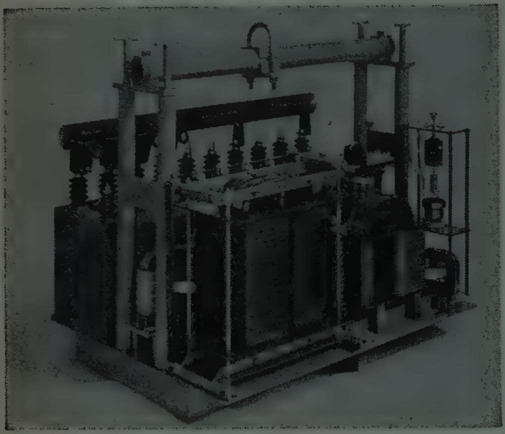
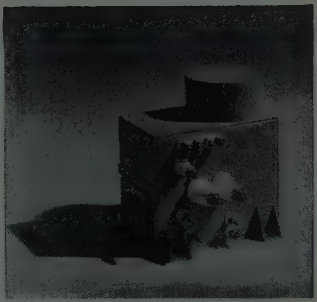


**2003**

235 KV peak at 10 μs pulse width
24 Megawatt peak pulse power
Approx. Size: 52″ l. x 42″ w. x 33″ h.
Approx. Weight: 1500 lbs.
Klystron: Eimac Type X-632

**2000**

22 KV peak at .1 μs pulse width
440 KW peak pulse power
Approx. Size: 4½″ l. x 3½″ w. x 7″ h.
Approx. Weight: 9.5 lbs.
Magnetron: Bomac Type BL213



**2001**

17 KV peak at .1 μs pulse width
230 KW peak pulse power
Approx. Size: 5½″ l. x 3³³⁄₃₂″ w. x 4¹¹⁄₁₆″ h.
Approx. Weight: 15 lbs. incl. tube
Magnetron: Raytheon Type QK400

carad corp
redwood city, california
2850 bay road • emerson 8-2969

## Membership

*(Continued from page 94A)*

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Silvey, J. O., Ft. Wayne, Ind.
Simonds, R. L., St. Joseph, Mo.
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Trent, J. E., Hopkins, Minn.
Trogdon, R. L., Urbana, Ill.
Tucker, M., Tahoe Valley, Calif.
Uncapher, K. W., Los Angeles, Calif.

*(Continued on page 102A)*

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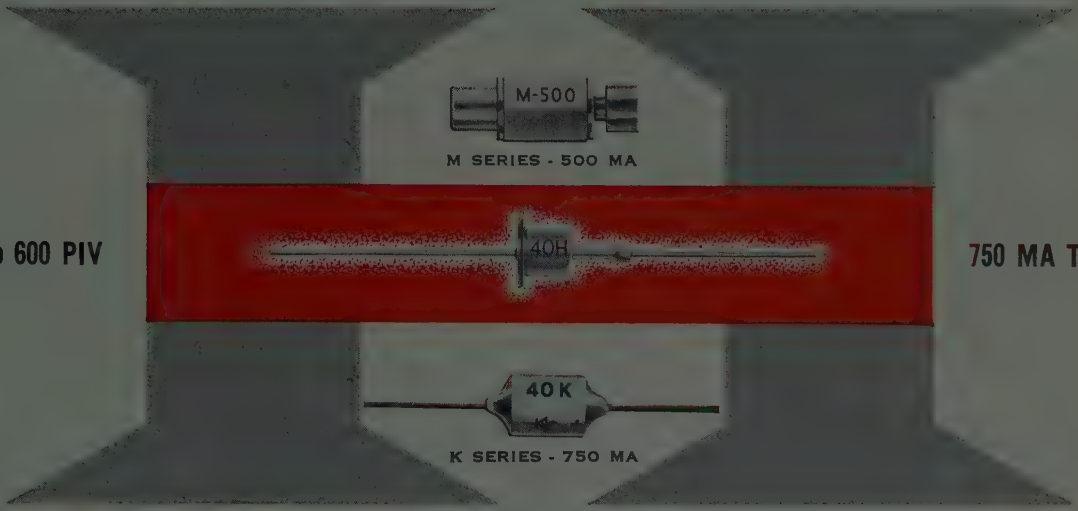
PHILCO CORPORATION
Lansdale Tube Co. Div.
Lansdale, Pennsylvania

# *Announcing* A NEW MEMBER OF THE Tarzian SILICON RECTIFIER LOW CURRENT FAMILY...

## The H Series

100 to 600 PIV



750 MA TO 55°C

RECTIFIERS ACTUAL SIZE

### ELECTRICAL RATINGS
CAPACATIVE LOAD

| S. T. Type | Max. Peak Inverse Volts | Max. RMS Volts | CURRENT RATINGS—AMPERES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Max. D. C. Load | | | Max. RMS | | | Max. Recurrent Peak | | | Surge 4MS Max. | | |
| | | | 55°C | 100°C | 150°C | 55°C | 100°C | 150°C | 55°C | 100°C | 150°C | 55°C | 100°C | 150°C |
| 10H | 100 | 70 | .75 | .5 | .25 | 1.875 | 1.25 | .625 | 7.5 | 5. | 2.5 | 30 | 30 | 15 |
| 20H | 200 | 140 | .75 | .5 | .25 | 1.875 | 1.25 | .625 | 7.5 | 5. | 2.5 | 30 | 30 | 15 |
| 30H | 300 | 210 | .75 | .5 | .25 | 1.875 | 1.25 | .625 | 7.5 | 5. | 2.5 | 30 | 30 | 15 |
| 40H | 400 | 280 | .75 | .5 | .25 | 1.875 | 1.25 | .625 | 7.5 | 5. | 2.5 | 30 | 30 | 15 |
| 50H | 500 | 350 | .75 | .5 | .25 | 1.875 | 1.25 | .625 | 7.5 | 5. | 2.5 | 03 | 30 | 15 |
| 60H | 600 | 420 | .75 | .5 | .25 | 1.875 | 1.25 | .625 | 7.5 | 5. | 2.5 | 30 | 30 | 15 |

### Features

- High Reliability—Extra Heavy Duty Junction
- Hermetically Sealed Welded Case
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# Introducing the Donner 3400

*10 Chopper Stabilized printed circuit amplifiers*

*Built-in 0.1% null voltmeter*

*Repetitive or continuous operation*

*Choice of 0.1% or 1.0% computing components*

## A NEW Desktop Computer WITH CHOPPER STABILIZED AMPLIFIERS

Donner's new 3400 analog computer combines high accuracy, flexibility, and economy. From its inception, design philosophy dictated the creation of a computer whose performance compared favorably with larger and more expensive equipment.

A complete Model 3400 consists of 10 chopper stabilized amplifiers, built-in null voltmeter and cyclic reset generator, 5 initial condition power supplies and supporting control and metering circuitry. Price of the basic Model 3400 is $2,190. The Model 3430 Removable Problem Board sells for $95. The purchaser can buy either 0.1% or 1.0% passive plug-in computing components according to the requirements of his problems. Two or more 3400's can be slaved together and operated from any one computer. Standard companion non-linear equipment such as function generators, and multipliers is available for operation with the 3400.

Donner engineering representatives are located in principal areas throughout the western world. Your nearest representative will be happy to arrange a demonstration. For the name of your nearest representative and complete technical information on the new Donner 3400, please address Dept. 4310.

**Model 3101 plug-in amplifier:** *dc gain in excess of 50 million; maximum offset of a unity inverter, less than 200 μv/day; drift of unity integrator, less than 100 μv/sec; phase shift of unity inverter, less than 0.5 degrees at 1 kc. These amplifiers are also available for separate sale.*

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# ELECTRONIC ENGINEERS

needed at

# MARTIN

New long-term developments at Martin in the field of electronics have created exceptional opportunities for top electronic engineers. At least 5 years experience required. Salaries from $9,000 to $15,000.

### Openings in these areas:

- Circuit Design
- Systems
- Inertial Guidance
- Countermeasures
- Digital Computers
- Test Equipment Design

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**MARTIN**
**BALTIMORE**

Truly sub-miniature, these capacitors were devised especially for printed circuits and automatic assembly. Since they retain all the properties of larger, pig-tail capacitors, they are well suited to general circuitry as well.

# Now—Corning Fixed Glass Capacitors in new sub-miniature size

**Packing up to 1,000 uuf at 300 V. and 125°C. into 0.010 cubic inches, these new capacitors are designed for use on printed circuit boards and all applications requiring high-quality components. Advantages include fixed temperature coefficient, high insulation resistance, low dielectric absorption, the ability to operate under high humidity and high temperature conditions, plus the added advantage of increased miniaturization.**

You can now up-grade your specs for miniature capacitors used on printed circuits.

These new capacitors measure only $\frac{9}{32}$ x $\frac{19}{64}$ x .115, yet have capacitances up to 1000 uuf at a full 300 V. rating at 125°C. Such exceptional thinness makes these capacitors particularly well suited for vertical mounting in small, high-rated units.

The capacitors have high temperature soldered leads which allow direct connection to circuit boards. The leads are .100 inches long, fitting most circuit board thicknesses and eliminating any trimming.

**Reliable** • Since the new construction is extremely simple, reliability is correspondingly high.

**Rugged** • These capacitors, when mounted, successfully withstand a standard five-hour vibration cycling test at 10 to 55 cycles, 15G Max.

Known as WL-4 capacitors, these units are in mass production. Your inquiries concerning data and prices are welcome.

FEATURES

1. to MIL C-11272A except smaller
2. 1 to 1,000 uuf
3. 300 volts
4. 125°C. full rating
5. .010 cubic inches

*Corning means research in Glass*

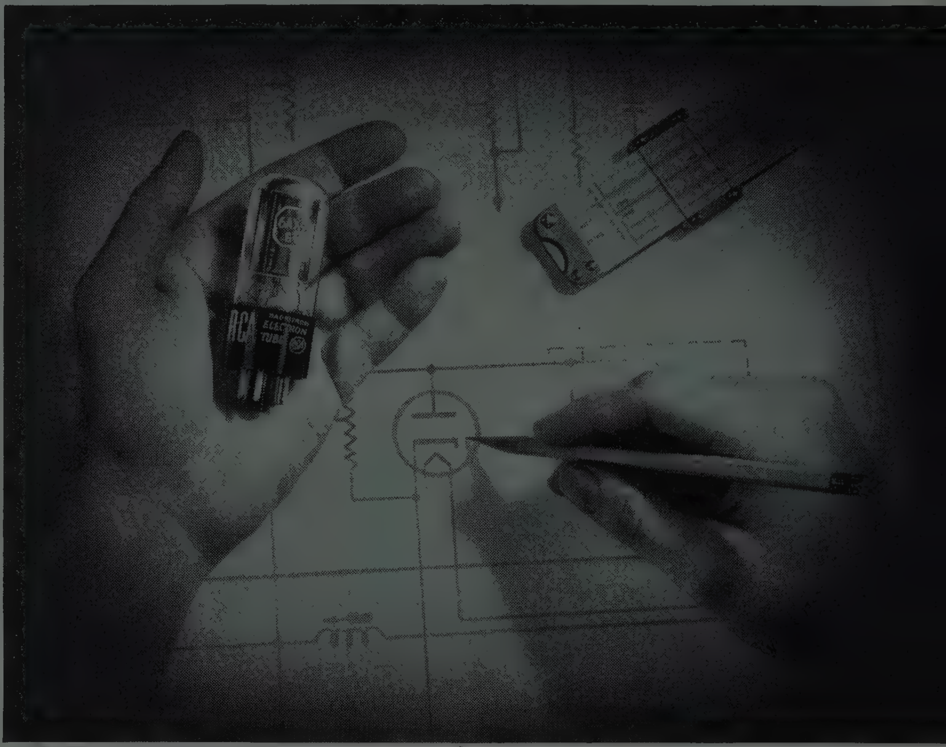
CORNING GLASS WORKS, Bradford, Pennsylvania
*Electronic Components Department*

# How RCA-6AX4-GT
# —A Preferred Tube Type—
# Improves The Reliability Of Damper Circuits!

In recent years, damper tubes for TV receivers have been subjected to increased demands of performance. RCA now offers and recommends the improved 6AX4GT, a Preferred Tube Type, designed for reliable performance under the severe requirements of modern TV receivers. RCA's ability to produce reliable tubes at low cost is at the heart of the Preferred Tube Types Program.

The RCA-6AX4GT exemplifies the benefits offered by the Preferred Tube Types Program. Outstanding among its features are: built-in safety factors that minimize internal breakdowns and reduce field service and replacement problems.

Heater wire has been especially developed to improve welds, thereby reducing early-hour failures due to an open circuit at the weld-point. Heater-spacer assemblies are pre-fired to eliminate contamination during tube production. And micas are specially sprayed to control plate-to-cathode leakage.



Popular RCA-6AX4GT offers high reliability, long life and improved performance for hard-working damper circuits—typical of the benefits you gain when you specify RCA Preferred Tube Types.

These important improvements, together with stringent quality controls and cycled operational tests that simulate in-home use, combine to produce a *highly reliable tube* deserving of its place on the Preferred Tube Types List—*and in your designs!*

For reliable circuit performance, design around RCA's Preferred Tube Types. Ask your RCA Field Representative for the up-to-date list of RCA Preferred Tube Types. Or, write RCA Commercial Engineering, Section J-35-Q. Harrison, N. J.

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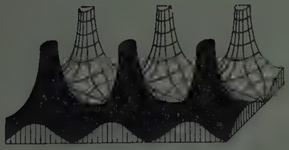
Los Angeles 22, California
RAymond 3-8361

**RADIO CORPORATION OF AMERICA**
**Electron Tube Division** **Harrison, N. J.**

*October, 1958*
*Vol. 46* *No. 10*

**Proceedings of the IRE**

# Poles and Zeros



**ECPD**—Since 1932 this grouping of letters of the alphabet has meant the Engineers' Council for Professional Development—a federation of engineering societies dedicated to sponsoring the intellectual development and professional interests of the individual engineer through intraprofessional activities. Now numbering eight, the participating societies are the ASCE, AIME, ASME, AIEE, AICHE, the Engineering Institute of Canada (EIC), the American Society for Engineering Education (ASEE), and the National Council of State Boards of Engineering Examiners (NCSBEE).

Financed from these societies and by grants from industries, foundations, and interested individuals, the ECPD has carried on a program whereby the progress of a young engineer toward professional stature can be recognized by the man, the profession, and the public. This program has been largely directed to four tasks: assuring entrance into the profession of young people having the necessary capacity and a truly professional aptitude; development of criteria for colleges of engineering that will insure their graduates having the requisite educational foundation; plans for integration of graduates into industry and professional practice; and methods of recognizing engineers who have met suitable professional standards.

These tasks have been carried forward through development of a guidance program for high school students, consolidation of engineering school accreditation into one agency designed to stimulate these engineering schools into positions of higher respect and excellence, development of community-wide training programs through which the engineering graduate can grow into the technical, professional, and civic life of his community, and finally, to provide certification procedures for public recognition of the engineer.

The accreditation program has now extended to both engineering colleges and technical institutes, and is probably the ECPD work of greatest interest to many IRE members who are recent graduates or are hopefully working toward The Day. Carried out by visiting teams of educators from other campuses, it could easily have degenerated into a "you scratch my back, I'll scratch yours" situation, but due to strong and clear-thinking leadership it has not done so. The inspections have encouraged forward-looking educational experimentation and advance, avoided acting as a strait-jacket, and served to spur the laggard. Who can say that convincing a botany- or history-trained dean of faculty or university president of the necessity for high-cost engineering facilities and staff may not have been ample justification for many accreditation visits?

Accreditation is by curriculum, giving no over-all whitewash for the weak department, and to date has led to approval of 811 curricula in 154 schools. While extending recognition to 22 different subject-matter curricula, we note that the majority of accreditations occur in the civil, electrical, and mechanical areas, with 133, 134, and 131 schools each. We might debate the advisability of the recognition of several of the more specialized areas, if we wanted more arguments than we now have.

The development of a professional spirit within the profession and of methods of ensuring that proper educational foundations are laid, and the program of professional integration into the community, certainly represent major achievements of the ECPD. Recognizing the importance of this work and desiring to undertake its share of the responsibilities engendered by the size and importance of the electronic field, the IRE Board of Directors at its Houston meeting in April, 1957, moved to petition for membership in ECPD. The ECPD charter was not then well-adapted to expansion of membership, and so admission has been delayed while the legal amenities were being met. Decision is awaited at the ECPD annual meeting in New York this month.

**Our Hucksters.** While to a few members the presence of advertising pages in the PROCEEDINGS is unfortunate, those who consider the other adjuncts of IRE membership, such as TRANSACTIONS, STUDENT QUARTERLY, Standards, CONVENTION RECORD, Section meetings, and the like, know the importance of the advertising pages. We have recently been rather amazed at another but somewhat concealed advantage, namely, the forceful monthly education in the news of the electronics field to be gained by perusal of the advertising pages. Such study can also go far to making one realize the speed with which our field is moving.

Taking the August issue as an example, there were 111 editorial and about 160 advertising pages. Counting only full page displays, there were 30 pages of advertising presenting the virtues of tried and proven products and 32 pages emphasizing the newly born ideas of our own minds, with 13 of the latter pages also featuring gadgets or systems of value to the itinerant space traveller of next year. As examples of newly born gimmicks, we can list Hall-effect diodes, synthetic garnet, silicone casting rubbers, ferrites, silicon capacitors, logarithmic microvoltmeters, solid-state controlled rectifiers, mesa transistors, and the like.

As a premium with our incomparable compendium of cyclopedic chatter, where else can you get a monthly education on the new gadgets which will do the job faster, finer, or financially frugaller than in the PROCEEDINGS advertising?

—J.D.R.

# *Allan B. Oxley*

*Director, 1957–1958*

Allan B. Oxley (A'25–M'33–SM'46–F'53) was born in London, England in 1901. He attended night school for thirteen years, and did postgraduate work in physics and atomic theory at the University of Toronto in 1929.

During the early years of his career he engaged in the manufacture of microscopes, spectrometers, and fine scientific instruments. From 1924 to 1926 he was mechanician to the Department of Physiology at the University of Toronto, and assisted Sir Frederick Banting in the development of insulin for diabetics. Later he helped form the Oxley and Meredith Company before his appointment as manager and chief engineer of the King Radio Corporation in 1927. He retained the position of chief engineer when the Williams Piano Company absorbed the King Corporation in 1929. In 1933, as chief engineer of the Philco Radio and Television Corporation, he was assigned to organize a factory in London. He returned to Canada in 1935 and became quality engineer, and then chief engineer, for the RCA Victor Company, Ltd., in Montreal.

During World War II he was responsible for several electronic research developments for the British, Canadian, and American governments.

Mr. Oxley has been active in the Canadian Region of IRE for more than thirty years. He assisted in the formation of the Montreal Section, was chairman of the Toronto Section in 1933, Chairman of the Montreal Section in 1939 and 1949, and served as Director of the Canadian Region in 1951–1952.

He is a past chairman of the Engineering Committee of the Radio Manufacturers Association of Canada, was general coordinator of the Canadian Radio Technical Planning Board from 1944 to 1948, and has been Canadian representative on the United States Electronic Industries Association Receiver Committee since 1939. He is a member of the Royal Canadian Institute and of the Corporation of Professional Engineers of Quebec.

# Scanning the Issue

**The Westrex StereoDisk System** (Davis and Frayne, p. 1686)—The widespread introduction of stereophonic records this fall ranks as one of the major milestones in the long history of the home entertainment field. Although stereophonic recording is 25 years old, it was not until 3 or 4 years ago that it made commercial headway with the release of stereophonic tapes and tape recorders for hi-fi enthusiasts. This fall stereo disks and record players are sweeping the industry, and by the end of the year every major recording company will be deeply involved in stereo. Broadcasters, too, are showing great interest. A substantial number of those who operate both an AM and FM station are now broadcasting stereophonic programs, one sound channel on AM and the other on FM, for listeners who have both types of sets in their homes. Also, an increasing number of FM broadcasters are multiplexing the two sound channels on the one FM channel for those who have special stereo adapters on their FM sets. This paper describes the stereophonic recording system that has been adopted by the industry, the so-called 45-45 system, the development that has ushered in the stereophonic disk recording era.

**ELF—A New Electroluminescent Display** (Sack, p. 1694)—Recent developments in improved phosphors have stimulated a great deal of interest in solid-state panel-type display screens in the past three years. A panel device offers important advantages over conventional cathode-ray-tube displays because the screen area can be made many times larger while the thickness is that of only a thin panel. Electroluminescent displays incorporating photoconductive elements have been successfully built for intensifying and displaying X-ray and light images. However, they are not amenable to displaying information that changes rapidly. The device described here offers an entirely new approach by using a ferroelectric structure in association with the electroluminescent material, resulting in important improvements, including the achievement of rapid scanning speeds approaching the range required for television.

**The Helitron Oscillator** (Watkins and Wada, p. 1700)—The continuing search for electron beam tubes that do not require cumbersome focusing magnets has led to the development of an important new type of magnetless backward-wave oscillator which appears to be a promising competitor to existing voltage-tuned microwave tubes.

**Guided Wave Propagation in Submillimetric Region** (Karbowiak, p. 1706)—TE waves have the interesting property that as frequency is increased in the kilomegacycle range, attenuation decreases rather than increases as in the case of TM waves. This paper discloses an even more unusual fact, unknown to most engineers, that as you continue to increase frequency well beyond 100 kmc and up into the infrared region, TM waves, too, show a decrease in attenuation. In fact, the rate of decrease is greater for TM than for TE waves. However, the TM attenuation curve does not catch up with, and cross under, the TE curve until the visible light region of the spectrum is reached.

**Solar Cycle Influence on the Lower Ionosphere and on VHF Forward Scatter** (Ellyett and Leighton, p. 1711)—Reflections from meteor trails are known to play an important role in ionospheric forward scatter, but it has not been clear whether scatter is due to meteoric ionization alone. A scatter communication link which has been in operation now for seven years has provided the authors the opportunity to compare long-term trends of changes in signal strength with the 11-year sunspot cycle. The results clearly show that the sun, too, exerts an effect on the magnitude of daytime scatter signals, thus filling an important gap in our knowledge of the ionizing agents of the lower ionosphere.

**On the Determination of the Electrodes Required to Produce a Given Electric Field Distribution Along a Prescribed Curve** (Kirstein, p. 1716)—This paper provides a method of calculating the theoretically correct electrode configuration needed to guide electrons through a vacuum tube along a desired trajectory, provided the trajectory can be expressed analytically. The method provides an important contribution to the design of electron guns and focusing systems, and will be of particular interest to those working with dense electron beams of the type used in many microwave tubes.

**A Voltage-Sensitive Switch** (Otley, *et al.*, p. 1723)—A small solid-state switch has been developed which may replace thyratrons and gas diodes in certain applications. It consists simply of a thin dielectric oxide layer formed electrolytically between two metal electrodes. Upon application of the proper voltage, the dielectric film breaks down and the switch functions. While its applications are limited to one-shot devices such as fuses, it represents a novel idea and an interesting use of breakdown phenomena.

**Methods of Measurement of the Parameters of Piezoelectric Vibrators** (Gerber and Koerner, p. 1731)—In 1957 the IRE issued a Standard specifying methods of measuring various quantities associated with piezoelectric vibrators. It was later adopted as an international standard at a meeting of the International Electrotechnical Commission in Zurich. The Chairman of the IRE piezoelectric committee, attending as a U. S. delegate, found there existed internationally an urgent need for more detailed information on the IRE measurement methods. To fill this need, he and a colleague have now detailed the theoretical considerations of these measurements and assembled useful charts and tables that relate measured and fundamental vibrator parameters.

**Harmonic Generation with Ideal Rectifiers** (Page, p. 1738)—Very few engineers are aware of the limitations on methods of generating harmonics with rectifiers. Intuition tells them that using ideal rectifiers and filters should make it possible to generate harmonics with high efficiency and without dc dissipation. This paper throws cold water on all such hopes by proving that the efficiency of generating the $n$th harmonic cannot exceed $1/n^2$ and that at least 75 per cent of the converted power is dissipated as dc.

**An Error-Correcting Encoder and Decoder of High Efficiency** (Green and San Soucie, p. 1741)—Although this paper is really directed at the specialist, the general reader will find the discussion of a novel triple-error-correcting code, how it is generated and decoded, and its error-correcting capabilities presented so clearly as to provide him with a fairly good understanding of a subject which is rapidly changing the character of the communications field from one of transmissions between humans to one of transmissions between machines.

**A Computer Oriented Toward Spatial Problems** (Unger, p. 1744)—Recent efforts to design machines that will recognize characters of the alphabet have opened up a broad field of pattern recognition problems that will soon engage the attention of many diverse segments of the profession. The computer described here presents a new approach to this important class of problems which, heretofore, has not been well suited to solution by computers.

**Distribution of Leakage Flux Around a TWT-Focusing Magnet—A Graphic Analysis** (Glass, p. 1751)—The fundamental design formulas and graphs presented here describe the distribution of external leakage flux around traveling-wave-tube magnets and will be a very useful aid in minimizing the amount of interference which this flux leakage frequently causes to other equipment in the vicinity.

**Scanning the TRANSACTIONS appears on page 1768.**

# The Westrex StereoDisk System*

C. C. DAVIS† AND J. G. FRAYNE†

*Summary*—**This paper describes the Westrex StereoDisk Recorder which records two stereophonic channels in a single groove with a single stylus. The axes of the two recordings are at 90 degrees to one another, each being at 45 degrees with the horizontal plane of the record. By use of appropriate input circuits, the vertical-lateral type of stereophonic record may also be recorded. The recorder utilizes the electrodynamic feedback features of the Westrex lateral recorder. The design features of the recorder are described and the performance is discussed. Data on channel crosstalk, intermodulation distortion, and frequency characteristics are given.**

**The design features and performance of the complementary StereoDisk Reproducer are described, including the desirability of maintaining the same vertical tracking angle in both recorder and reproducer. This reproducer employs dual d'Arsonval movements resulting in an exceptionally faithful reproduction.**

THE current interest in stereophonic sound reproduction in the home has stimulated the development of the two-channel stereophonic disk system described in this paper. It is not generally recognized that considerable research was carried on in the 1930's on this type of stereophonic recording in which two channels are recorded in a single groove. For example, Blumlein of EMI in England was granted British Patent No. 394,325 in 1933 on a two-channel stereophonic system. He disclosed the possible use of a vertical-lateral combination to produce a stereophonic effect. He also called attention to the 45-45 orthogonal system as an alternative method. At the Bell Telephone Laboratories, Keller and co-workers made stereophonic recordings as early as 1936, and Keller and Rafuse were granted U. S. Patent No. 2,114,471 in 1938. Blumlein and Keller built their experimental stereophonic recorders by linking existing lateral and vertical recording mechanisms. U. S. Patent No. 2,025,388 issued to Henning of Bell Telephone Laboratories disclosed a reproducer capable of reproducing either vertical or lateral recordings. By using suitable output circuitry, Henning's reproducer has been successfully used to reproduce the Keller and Rafuse vertical-lateral recordings. The emphasis on defense work at the Bell Telephone Laboratories in the late '30s, coupled with apathy on the part of commercial recording concerns, caused this development to be laid aside.

In developing the Westrex StereoDisk System, the authors were primarily interested in the development of a stereophonic system in which the two channels would give as nearly identical quality as was possible to achieve. In arriving at this conclusion, they were mindful of the work of Pierce and Hunt[1] in their comprehensive theoretical analysis of the lateral and vertical modes of disk recording in which they predicted the amount and type of distortion products obtained by tracing both lateral and vertical grooves. While this and other considerations enumerated below were important factors in support of the 45-45 orthogonal system, the symmetry of design it made possible for both recorder and reproducer was probably the determining factor. Further, the 45-45 system was capable of producing the vertical-lateral type of stereophonic disk if this method had been adopted by the industry.

## GENERAL DESCRIPTION OF 45-45 SYSTEM

Having decided in favor of the 45-45 system, the next step was to evaluate design objectives in both recorder and reproducer in order to obtain a satisfactory stereophonic recording system for disks. A primary design objective in a dual channel stereophonic system is to obtain identical characteristics in the two channels. In the case of a disk recorder this means the stylus mounting mechanism must have equal compliance in all directions in a vertical plane normal to the recorded groove. If the recorder is to use moving coils they should be identical and they should operate in identical amounts of magnetic flux. The coils should move the stylus through identical mechanisms. If this primary objective is not met, one channel must necessarily be inferior to the other in one or more respects requiring an unnecessary amount of effort to adjust and maintain the system for reliable commercial recording. It can be stated that consideration of this basic objective was an important factor in the adoption of the 45-45 method of recording. The final recorder design met the objective and also was capable of recording a vertical-lateral type of record while preserving the symmetry called for above.

It was decided that the new recorder should retain the feedback principle which has been an outstanding feature of both the Western Electric and Westrex recorders for the past 20 years and has been described previously.[2] This involved the mounting of a pickup coil on each of the drive assemblies in the recorder and including these coils in the feedback loops in the respective recording amplifiers. The design constants of the

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[1] J. A. Pierce and F. V. Hunt, "Distortion of sound reproduction from phonograph records," *J. Soc. Motion Picture Eng.*, vol. 31, p. 157; August, 1938.

[2] L. Vieth and C. F. Wiebusch, "Recent development in hill and dale recorders," *J. Soc. Motion Picture Eng.*, vol. 30, p. 96; January, 1938.

feedback circuit were of necessity a compromise of factors imposed by the design and performance requirements. The details of the feedback circuit are covered in the description of the recorder.

As a result of these considerations a feedback of approximately 27 db at the resonant frequency was employed. This held up the high-frequency response to at least 15 kc and the low-frequency response was brought up by the use of passive networks preceding the recording amplifiers. This arrangement of feedback maintained good stability over the significant range of audio frequencies, and, with the aid of the passive networks, essentially constant-velocity recording was provided over a frequency range from 30 to 15,000 cps, except for a very narrow dip of a few db in the vicinity of 11,000 cps. This characteristic is modified in commercial practice by inserting the RIAA or equivalent recording preequalization characteristic.

Two recording amplifiers, one for each channel, are required to operate the recorder. The circuits of the amplifier are shown in Fig. 1 in block-schematic form since the details of design are not considered significant for this presentation. The recording circuit consists of a phase-inverter stage which drives a push-pull gain stage which in turn drives a push-pull, parallel power stage. The four-ohm output goes to one drive coil in the recorder. Adjustable low-frequency and high-frequency equalization is provided ahead of the phase-inverter stage. The output of the feedback coil in the recorder goes through a gain control to a gain stage. The output of this stage goes to the grid of the phase-inverter tube which also acts as a mixer. The output of the feedback coil also goes to a two-stage monitor-amplifier which has a 600-ohm or 50-ohm output at a nominal monitor level of −15 dbm. The input network of the monitor amplifier provides the RIAA reproducing equalization.

Since the characteristic of the network used to provide constant-velocity recording is to some extent complementary to the RIAA preequalization recording characteristic, the two characteristics can be combined in a single equalizer with a considerable reduction of insertion loss.

The development of a reproducer was undertaken with the design objective of providing the highest quality of reproduction attainable. The three well-known basic principles of reproducer design were considered and the electrodynamic or rotating-coil type was selected as affording the best opportunity of meeting the design objective. Theoretical consideration indicated this type would provide appropriate compliance and low mass at the stylus compatible with basic requirements. It was indicated also that a satisfactory frequency response over the audio range with relatively low intermodulation and harmonic distortion might be expected. The details of design and performance of the reproducer are described elsewhere in this paper.

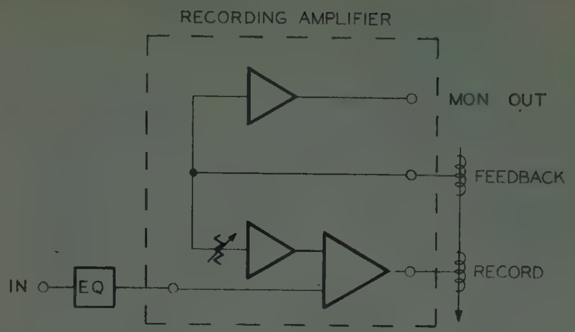

Fig. 1—Block schematic of recording amplifier.

## COMPARATIVE PERFORMANCE OF V-L AND 45-45

A comparison of the relative performance capability of the vertical-lateral (V-L) and the 45-45 systems will indicate the reasons for the preference of the latter system. An analysis of the stereophonic groove cut with either the 45-45 or V-L system will show considerable similarities between the two types of recording. Thus, with the 45-45 system, both lateral and vertical modulated grooves will result, depending on the phase relationships of the inputs. For random phase differences, a complex groove with both vertical and lateral components will be recorded. On the other hand, with the V-L system, vertical and lateral tracks will result only when one or the other microphone receives no signal. For the general case where sound is picked up by both microphones, the resultant groove will have both vertical and lateral components and will appear to be substantially the same as a groove cut with the 45-45 system.

In the V-L system, we might expect a preponderance of either vertical or lateral cut grooves while in the 45-45 we might expect a preponderance of 45-degree modulations. Thus, the limitations on groove depth imposed by recording vertical components should be more severe than in the 45-45 system. In addition, by deliberately phasing the channels in the 45-45 system so that in-phase signals are recorded laterally, the limitations imposed by the vertical components are further reduced. Because of this situation, we would expect greater quality differences between the two channels in the V-L system due to the inherent but different tracing distortion components in the vertical and lateral grooves.[1]

The symmetry of the 45-45 system is not only of importance in balancing the quality of the reproduction from the two grooves, but has certain other very important by-products. In the record changer the vertical component of rumble is generally more pronounced than the horizontal component; this means more audible rumble in one channel in the V-L system, which is highly undesirable from a listening standpoint. In the 45-45 system, rumble should be identical in both channels and lower by about 3 db than in a strictly vertical channel. Another byproduct favorable to the 45-45 sys-

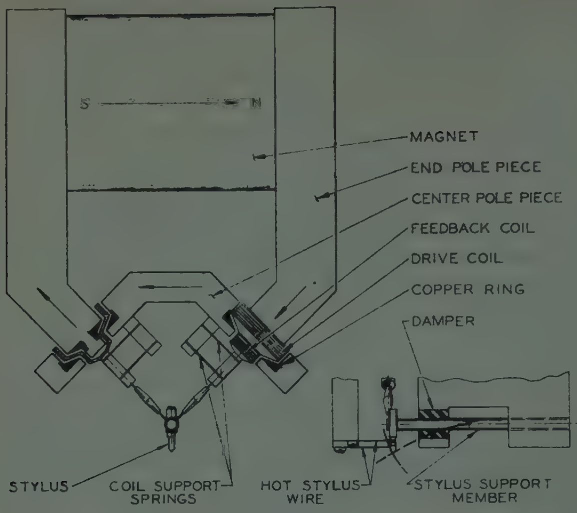
S
N
MAGNET
END POLE PIECE
CENTER POLE PIECE
FEEDBACK COIL
DRIVE COIL
COPPER RING
DAMPER
STYLUS
COIL SUPPORT SPRINGS
HOT STYLUS WIRE
STYLUS SUPPORT MEMBER

Fig. 2—Simplified recorder illustration.

tem is the ease of balancing the reproducing channels in the home. It is only necessary to play a standard lateral record and adjust the channel gain for equal loudness.

In the 45-45 system each channel will have lateral and vertical components of the impressed modulation. Thus it should be possible to reproduce either the lateral or vertical components of both channels with a standard lateral or vertical reproducer. Since vertical-type pickups are rarely encountered in home reproducing systems, the lateral type of pickup only needs consideration. If this type of reproducer has good vertical compliance it should be able to reproduce satisfactorily the lateral components of both channels. In this sense the 45-45 system of stereophonic recording is compatible with lateral records. This cannot be said of the V-L system since the lateral component represents only one of the recording channels.

## Design Details of Recorder

Fig. 2 illustrates the basic design of the recorder. The magnetic gaps of the drive and feedback coils are arranged in a series parallel fashion. The magnetic flux is provided to the system by a single magnet made from Alnico V D.G. This arrangement of magnetic paths insures equal flux densities in the corresponding gaps. Each of the magnesium coil forms contains a drive and feedback coil as shown. The shaded areas between the magnetic gaps indicate copper slugs or shields which reduce inductive crosstalk from the drive coils to the feedback coils. This crosstalk must be minimized to utilize the advantages of negative feedback control of the drive coil motion. Fig. 3 is a bottom view of the recorder. The individual coil assemblies are mounted on removable subassemblies, and are shown together with the other principal components in Fig. 4. This permits their alignment in an assembly jig as self-contained units before installation. The coil forms have small terminals which are in turn connected through pigtails to corresponding stationary terminals on the assembly. This arrangement eliminates breakage of these vital connections to the coils due to vibration and it simplifies examination or service of these parts. The coil-supporting springs are made from beryllium copper and are V-shaped to maintain the coils in proper alignment. The coils drive the stylus supporting member through separate linkages. These linkages consist of wires braced along their midsections to prevent excessive lateral compliance. The result is a relatively stiff driving system in a forward direction but with relatively high compliance in a lateral direction. This important relationship avoids the necessity of one coil bearing the mass of the other coil which would result if the coils were rigidly mounted on the stylus supporting member. Thus the mass of each driving system includes only its components and a negligible portion of the other driving system.

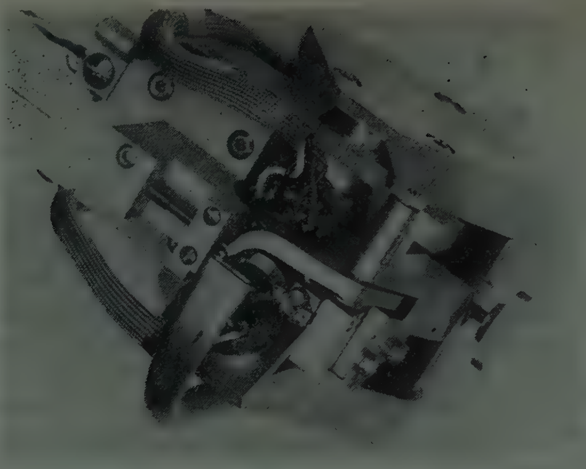

Fig. 3—Bottom view of 3A StereoDisk Recorder.

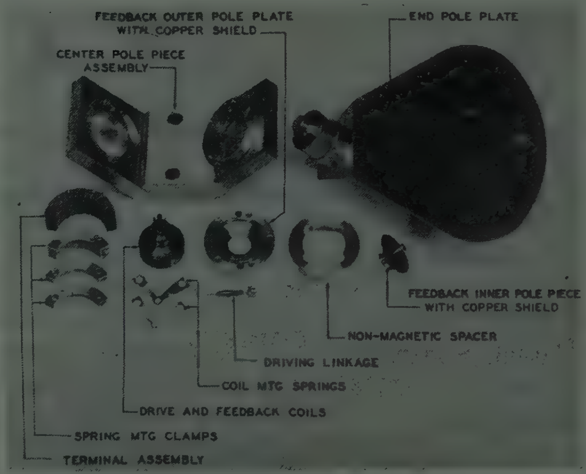
FEEDBACK OUTER POLE PLATE WITH COPPER SHIELD
END POLE PLATE
CENTER POLE PIECE ASSEMBLY
FEEDBACK INNER POLE PIECE WITH COPPER SHIELD
NON-MAGNETIC SPACER
DRIVING LINKAGE
COIL MTG SPRINGS
DRIVE AND FEEDBACK COILS
SPRING MTG CLAMPS
TERMINAL ASSEMBLY

Fig. 4—View of significant parts of recorder.

A tubular cantilever spring was chosen for the stylus supporting member because of the many advantages it offers. Its compliance as a cantilever is inherently the same in all directions in the desired plane, which is essential in order that the complex motion of the stylus may present uniform impedance in any direction in the vertical plane. This is particularly important at those portions of the frequency spectrum where the negative feedback voltage has little control of the stylus motion. Another feature of a tubular cantilever is its relatively low rotational compliance, which reduces the tendency toward crosstalk from one channel to the other.

The damper shown on the stylus supporting member has little or no effect below 10 kc and very little effect above 10 kc on the actual recording. It is used mainly to smooth out several peaks and valleys in the monitor output reading. Therefore, the effects of temperature and other factors upon the damper in no way affect the system damping, which is, of course, supplied by the feedback coil and the associated negative feedback loop in the recording amplifier.

The stylus has a tapered shank and is of the same type as those used in the 2B Recorder. The included angle of the stylus has only second-order effects on the recording. The same type of hot wire terminals are used to record with a heated stylus. Inasmuch as it appears impractical to hinge the stylus mounting mechanism of a recorder or reproducer exactly at the surface of the record a vertical tracking error will be introduced unless very nearly the same angle is used in the recorder and reproducer. What is normally considered as "vertical" motion of the cutting stylus tip in the recorder is actually at an appreciable angle from a vertical line. It does not seem practical from the standpoint of construction of both recorder and reproducer for the situation to be otherwise. The angle for the recorder is nominally 23 degrees, in a direction such that with upward stylus motion, there is a component in the direction of travel of the record surface. This angle was determined by measurements on an actual stylus supporting member and a mock-up stylus, and was confirmed by calculations.

### Description of 45-45 Groove

The geometry of the groove cut by the 45-45 recorder with a stylus having a cutting angle of 90 degrees merits consideration in some detail. Fig. 5 shows schematically cross sections of the groove for four limiting conditions. The upper left section shows the type of groove which will be cut when signal is fed only to the left channel. The right-hand groove wall is a slant line of varying depth. The right edge of the groove at the record will be a smooth line without modulation. The left edge of the groove will vary in width in accordance with the signal. The upper right section of the figure depicts the opposite condition in which signal is fed only to the right channel. It will be noted that the conditions are just reversed. The lower left section shows the type of groove which is cut when identical signals are fed to the two channels and are in phase at the drive coils. Under this condition a vertical recording is obtained. The lower right section shows the condition when like signals are fed to the two channels but out of phase at the drive coils. Under this condition a lateral recording is made. Any combination of these four conditions in varying amplitudes may occur in recording stereophonic program material.

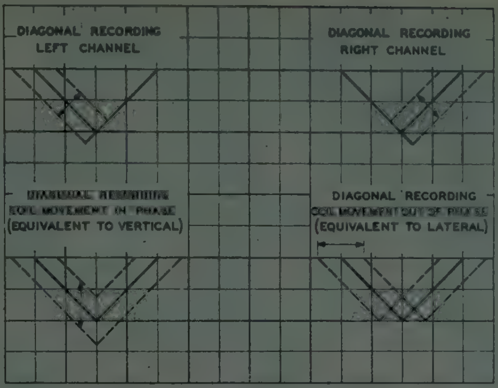

Fig. 5—Cross section of 45-45 grooves for four limiting conditions.

Fig. 6 is a photomicrograph of grooves recorded first with a single frequency on one channel and then on the other. One side of each groove is essentially straight while the other varies in width in accordance with the lateral component of the signal. The vertical component of the signal is shown by the varying shading in the photograph. Fig. 7 is a photomicrograph of grooves recorded using program material and a stereophonic pickup. Here again the lateral components are shown by the varying width of the grooves while the vertical components are represented by the varying shading in the photograph. Some of the vertical components in this picture represent frequencies of 12 kc or higher.

Fig. 8 shows the maximum excursion of a groove which will be cut with a given maximum amplitude of modulation of the drive coils and with a specified minimum depth of groove. The specified minimum groove depth is $D$ and the maximum modulation amplitude of either coil is $A$. Under these conditions the maximum horizontal excursion of groove will be $2D+4\sqrt{2A}$ and the maximum depth of groove will be $D+2\sqrt{2A}$.

The relative output level from a groove of specified maximum width recorded with the 45-45 system is a matter of considerable interest. Fig. 9 shows a comparison of this type of groove with the conventional lateral groove. In each case the specified maximum groove excursion is $2D+2A'$. In the lateral groove the maximum amplitude of modulation is $A$ which is equal to $A'$. In the 45-45 groove the amplitude of modulation in either channel is $A'/\sqrt{2}$. Accordingly the output of each of the 45-45 channels will be down 3 db with respect to the output of the lateral channel. For these conditions the playing time will be the same with the 45-45 system as for the standard lateral recording.

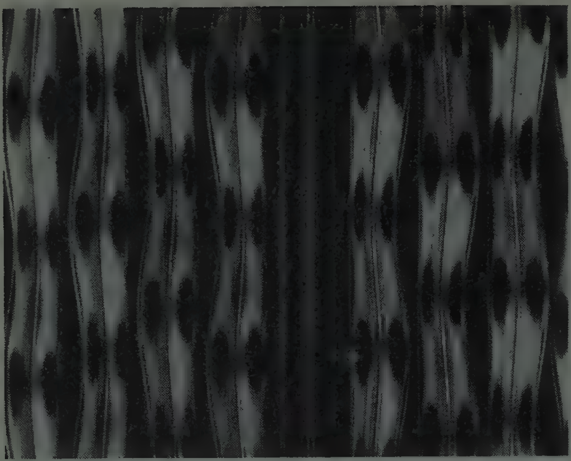

Fig. 6—Photomicrograph of single-channel 45-45 grooves.

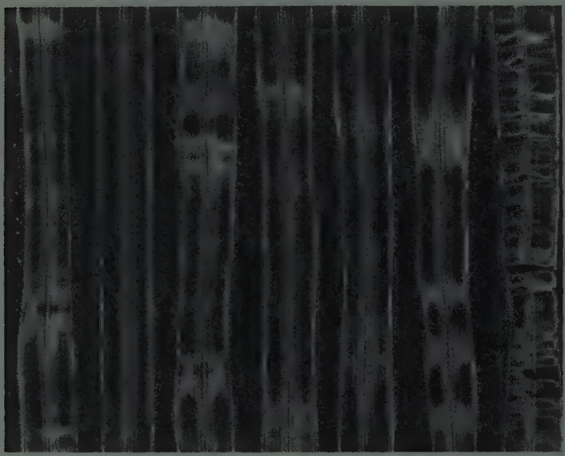

Fig. 7—Photomicrograph of 45-45 grooves with stereophonic program material.

## Performance of the Recorder

Fundamentally the performance of the recorder is based upon the use of moving coils with negative feedback control. The use of feedback to control resonance effects in vibratory systems was suggested first by Maxfield and Harrison.[3] The advantages of this type of transducer have often been described.[2,4] The moving coil offers a maximum of motional linearity and when combined with negative feedback it comprises a stable well damped system without resistive losses.[5] However, high efficiency must be obtained to provide the recorded levels used currently without excessive power losses which might destroy the coils with excessive heat. In order to achieve a practical physical size, the component parts of the magnetic circuits of the dual channel recorder must occupy a limited amount of space. To offset this condition two design features were incorporated:

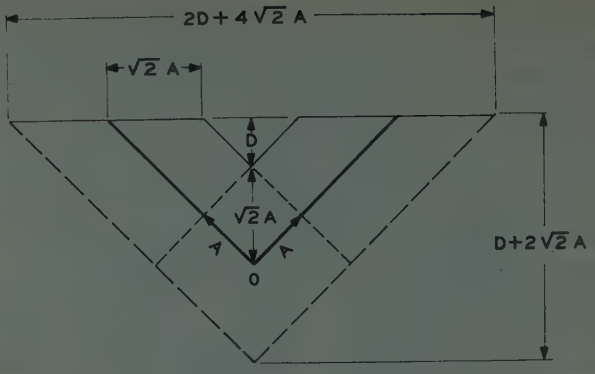

Fig. 8—Cross section of 45-45 groove for maximum groove excursion $D$ = specified minimum groove depth; $A$ = modulation amplitude.

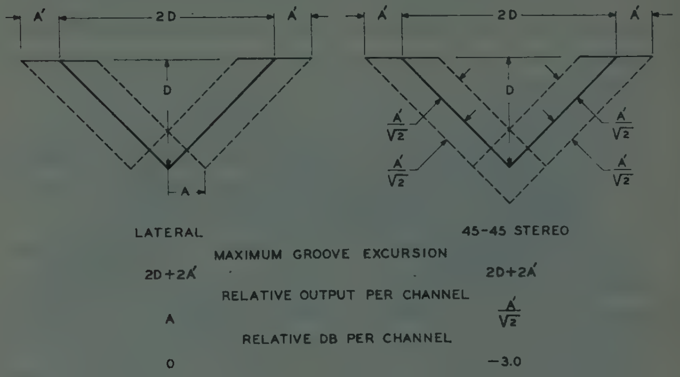

Fig. 9—Comparison of 45-45 with standard lateral groove.

1) minimum mass of the drive and feedback coils was used;
2) the natural resonant period of the vibrating system was made relatively high.

Since it is unnecessary to generate sufficient feedback voltage to control the system throughout the entire audio band if equalization is used at one or both extremes, the physical size of the feedback coil and its operating flux may be reduced. Thus the mass of the vibrating system may be reduced and the relative amount of flux at the drive coil increased.

The natural frequency of the vibrating system is placed about one octave above the geometric mean frequency. This results in power economy in the high-frequency range where considerable power is normally required with the RIAA type of preequalization. The amount of feedback at resonance is approximately 27 db. This is sufficient to control the stylus throughout the range of frequencies where the mechanical impedance of the vibrating system is low. This is the range where variable cutting resistance presented at the stylus may cause nonlinearity or wave distortion. Below this range the system is controlled by stiffness and is unaffected by cutting conditions. Throughout this range preequalization is required due to the loss of feedback control. Preequalization is not needed at high frequencies for a constant velocity recording characteristic.

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[3] J. P. Maxfield and H. C. Harrison, U. S. Patent No. 1,535,538.

[4] G. R. Yenzer, "Lateral feedback disc recorder," *Audio Eng.* (Audio Eng. section), vol. 33, p. 22; September, 1949.

[5] C. C. Davis, "A moving-coil feedback disk recorder," *J. Audio Eng. Soc.*, vol. 2; October, 1954.

The copper shields between the drive and feedback coils are intended to prevent inductive crosstalk between the drive coil and feedback coil. The effectiveness of these shields is at a minimum at about 200 cycles. Here the inductive crosstalk is −50 db relative to perfect coupling (*i.e.*, the coils used in a perfect transformer). Since the feedback voltage generated by the velocity of the coil is already low, the inductive crosstalk and the feedback voltages are of the same order of magnitude. Therefore, the apparent feedback voltage reads proportionately higher at low frequencies than that represented by the recording and the feedback voltage cannot be used to calibrate low-frequency response without calibration data. This condition in no way contributes to instability and the system is inherently stable.

Single-frequency power measurements give little useful information from feedback recorders. In order to arrive at a practical evaluation of the power required by program material with an RIAA preequalizer, records were made at high levels from orchestral and vocal numbers. These were made from a single-channel source connected to the recorder and phased to produce lateral-type recording. The material was of the type containing high-level sounds which produce extreme velocities with RIAA preequalization. The highest peak velocity recorded was 19 cm/second as measured with the light-band method. The highest rms value of current through one drive coil was 0.6 ampere. Therefore, the maximum power consumed by each 5.6-ohm coil was approximately 2 watts. The maximum groove swing was ±1.65 mils which indicates this was a high-level microgroove recording. It is doubtful if this level will be reached in stereophonic recording on disks with the normal pre-equalization characteristic.

The complex stylus driving mechanism of the 3A Recorder must necessarily contain additional masses and compliances not found in single-channel recorders. The recorded product covers the extremes from vertical through 45-degree recording to lateral recording. Differences in characteristics are to be expected under these conditions. Lateral recording is most subject to the effects of lateral stylus rotation at high frequencies. Rotation produces dips in level as well as interchannel crosstalk. Vertical recording appears to contain a minimum of rotational effects. At this point in the development of the recorder it is difficult to attempt a true evaluation of the amount of crosstalk and the frequency response of the recorder above 8 kc. It may be stated the average amount of modulation on the record when viewed optically appears higher at high frequencies up to 20 kc than at midrange frequencies. The curve in Fig. 10 is indicative of the response of a single 45° channel with a calibrated reproducer. The recording was made with a production recorder on a lacquer disk at 33⅓ rpm and at an approximate diameter of 10 inches.

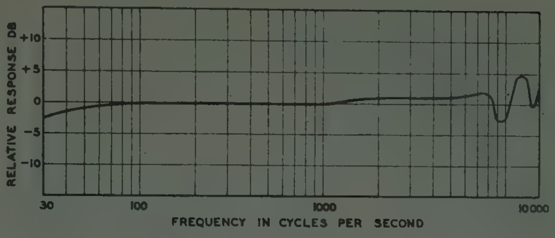

Fig. 10—Typical recorded frequency characteristic.

## REPRODUCER DESIGN

In order to facilitate the description of the reproducer, it is desirable to review in greater detail the design objectives which should be met. The mass of the moving assembly, including that of the coils, was made as small as possible, consistent with appropriate strength and adequate output level. Stylus compliance was next chosen of such a value as to give approximately equal reactances of the stylus against the record groove wall at 400 and 8000 cps, the frequencies which represent the approximate range of program material of equal velocity on the record. An additional requirement of the compliance was that the static deflection of the stylus due to the tracking force was to be large compared to the maximum deflection due to record groove vertical modulation. This was necessary to insure that the stylus would not lose contact with the record. High torsional stiffness at the stylus was an obvious necessity to restrict the stylus movement to one of translation and not of rotation. The stylus radius of 0.70 mil was chosen as a good compromise between a small radius for low distortion and good high-frequency response vs a large radius for long record life. Stylus force was chosen as the minimum value which would provide tracking at the highest recorded levels normally encountered.

The electrodynamic or rotating-coil movement was selected as affording the best means of meeting these requirements. Fig. 11 is an illustration showing a simplified front and side view of the principal operating components of the reproducer. The two coils are self-supporting and are mounted on Mylar hinges with the coil axes at right angles to each other and at 45 degrees with the horizontal. The lower edge of each coil is connected by means of a link to a beam in which the stylus is mounted. The beam (which actually is not subjected to bending or twisting) consists of a hollow tube whose outside diameter is 0.031 inch and whose length is approximately 0.15 inch. The rear of the beam is anchored in a flat spring which prevents rotation and at the same time provides essentially equal compliance at the stylus in any direction in the vertical plane. Some mechanical damping is applied to each link close to the coil by introducing a block of viscous semisolid material between each link and the reproducer housing. This reduces the height of a peak in the frequency response characteristic at about 11 kc and also reduces crosstalk between chan-

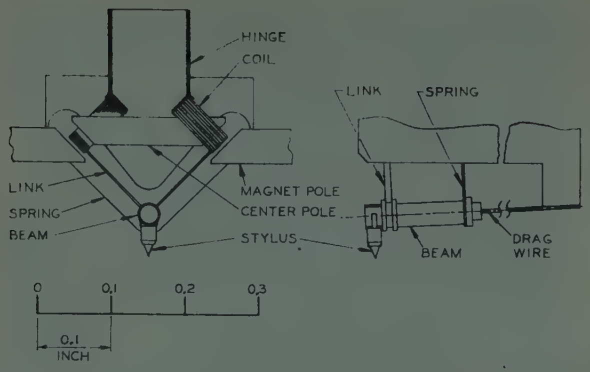

Fig. 11—Simplified reproducer illustration.

nels. The drag wire prevents longitudinal motion of the stylus. It will be observed that the beam is tilted downward at an angle of approximately 3 degrees with respect to the horizontal when the stylus is free. However, when the stylus rests on a record the beam is in a horizontal plane and parallel with the record surface. The vertical angle of the reproducer stylus motion has been made to conform closely with the angle of the stylus motion in the recorder to avoid the introduction of harmonic distortion in the vertical component of the reproduced signal. The vertical angle of stylus motion was mentioned briefly in discussing the recorder and was stated to be nominally 23 degrees. The reproducer has been designed to provide a corresponding angle of deviation from the vertical plane.

The angle difference between recorder and reproducer introduces tracking angle errors and is subject to the same mathematical analysis as tracking angle errors in lateral disk systems. Considerable literature has been published on this subject.[6]

The applicable equation for a velocity-sensitive reproducer to a close approximation is:

$$D = \frac{0.2 \times A \times M}{R}$$

where

$D$ = per cent of second harmonic distortion at $33\frac{1}{3}$ rpm,
$A$ = tracking angle error in degrees,
$M$ = modulation velocity (cm/second peak),
$R$ = distance of groove from record center (inches).

Fig. 12 is a family of curves obtained by the use of this equation which shows the amount of second-harmonic distortion for various amounts of tracking angle error. The curves are for grooves cut at constant velocity and at different distances from the record center. In Fig. 13 the second harmonic distortion is shown for various groove radii for a constant tracking angle error and at two recorded velocities. In both cases the amount of distortion is reduced to 63 per cent of the values shown, by the average 4-db-per-octave slope in the RIAA reproducing characteristic.

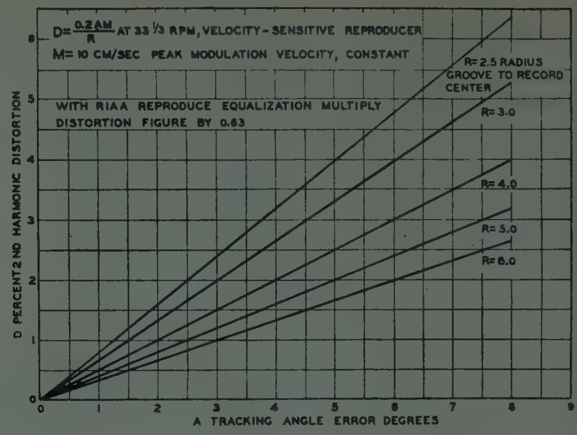

Fig. 12—Distortion vs tracking angle error.

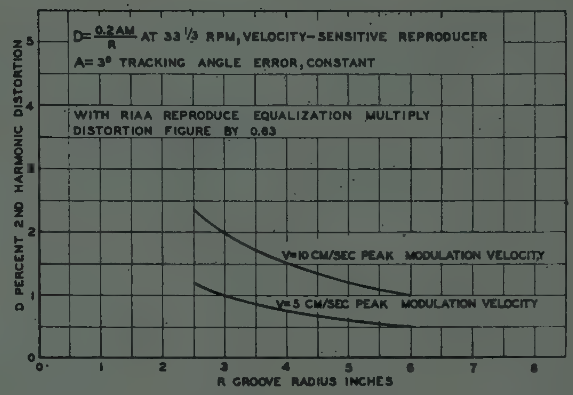

Fig. 13—Tracking angle distortion vs groove radius and recorded velocity.

Referring to Fig. 11, the magnetic path consists of a center pole piece, two magnet pole pieces, and a magnet. The latter is not shown. One edge of each coil is disposed in one of the gaps between the center pole piece and the magnet pole pieces. The polarity of the coil leads is so arranged that a laterally modulated groove will produce signals which are in phase in the output circuits.

Fig. 14 is an outside view of the reproducer. It is entirely enclosed except for the small clearance hole for the diamond stylus and it mounts in a standard reproducer arm. It tracks properly with six grams of stylus force. The stylus compliance is nominally $2.6 \times 10^{-6}$ cm/dyne and the dynamic mass is 3.0 mg. To avoid the difficulties involved in winding the moving coils with a large number of turns of extremely fine wire, a wire size has been chosen that results in a low output impedance of 2.4 ohms and a correspondingly low output voltage of 2 mv rms per channel for 10 cm/second peak velocity. A pair of transformers is therefore required for good signal-to-noise ratio.

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[6] B. B. Bauer, "Tracking angle in phonograph pickups," *Electronics*, vol. 18, p. 110; March, 1945.

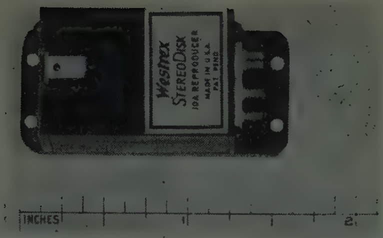

Fig. 14—View of 10A StereoDisk Reproducer.

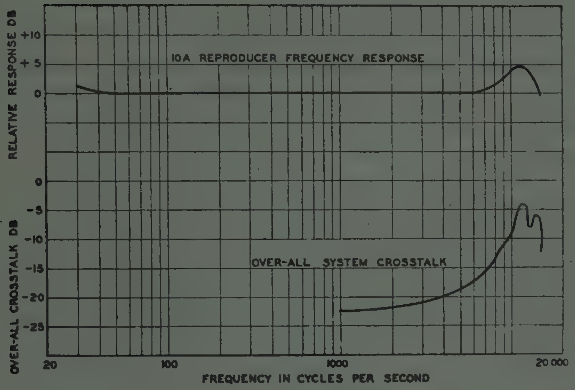

Fig. 15—Reproducer frequency characteristic and system **crosstalk.**

A typical frequency response of one channel of the reproducer is shown in Fig. 15. This characteristic was obtained by reproduction from an optically calibrated pressing containing single-channel test frequencies recorded at 45 degrees. The slight rise at the low-frequency end of the curve is the result of the resonance of the arm mass with the stylus compliance and it will vary somewhat with the mass of the arm employed.

## TRACING DISTORTION

Recordings made with the 45-45 method may vary all the way from single-channel 45-degree records to all vertical or all lateral types. Therefore a single 45-degree channel may receive the same information from any of these types. However, tracing distortion may be expected to exhibit different characteristics in all three cases due to the differences in tracing distortion between vertical and lateral or combination recordings thereof.

The following distortion measurements were made from records recorded under all three conditions. The input level per channel was the same in all cases. The recorded velocity was 2.5 cm/second (peak) per channel. This resulted in an amplitude variation of ±0.55 thousandths of an inch at the 400-cycle fundamental frequency.

Fig. 16 shows the total harmonic distortion as measured through the usual high-pass filter measuring device.

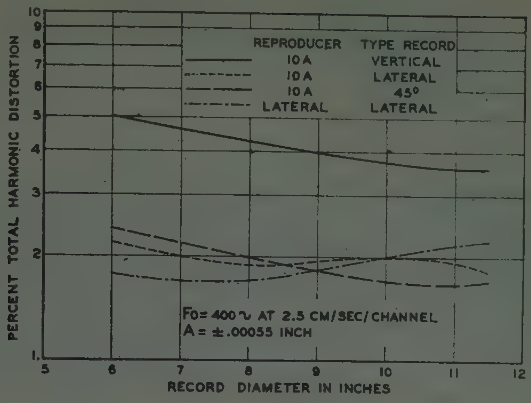

Fig. 16—Harmonic distortion curves.

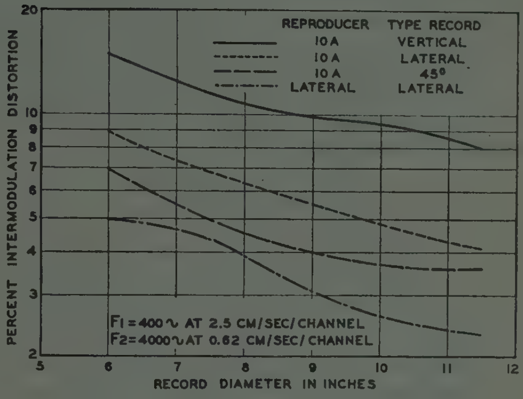

Fig. 17—Intermodulation distortion curves.

Fig. 17 shows the intermodulation distortion measured with the RA-1258 Intermodulation Generator and the RA-1257 Intermodulation Analyzer.

The system of stereophonic recording on disk described in this paper appears to give highly satisfactory two-channel stereophonic reproduction. The crosstalk of the over-all system shown in the lower curve in Fig. 15 appears to be entirely satisfactory for stereophonic listening and the frequency response is entirely adequate for high-fidelity reproduction in the home. Experience to date indicates little if any added problems in producing pressings with a low noise level. The system has been demonstrated widely to representatives of the disk recording studios and reproducing equipment industries both here and in Europe. A limited number of 3A Recorders have been placed in the hands of several recording companies and experimental disk recordings have been made available by some of them. Interest shown by industry and the public in the demonstrations of the 45-45 StereoDisk System would appear to confirm the soundness of this approach to the application of stereophonic recording principles to the field of disk recording.

# ELF—A New Electroluminescent Display*

E. A. SACK†, MEMBER, IRE

**Summary—The ELF screen is a new, flat electroluminescent display which combines very desirable brightness and halftone characteristics with flexible storage capabilities and high scanning speeds. There is no theoretical limitation on the area of the screen.**

**Ferroelectric ceramics are associated with the electroluminescent layer to proved built-in storage and control. The output image is formed in accordance with a charge pattern deposited on the ferroelectric control array. This pattern is established by a signal distribution system, part of which may be incorporated in the screen structure.**

**Highlight luminances in excess of 25-foot lamberts have been obtained with contrast ratios of over 50/1 in multielement models. Images may be stored for several minutes or, alternatively, the images can be modified many times per second. Model screens have been built with resolutions of from 4 to 10 elements per inch. Higher resolutions may be obtained by new techniques. A scanning system has been constructed which can distribute the picture information at microsecond switching rates.**

## INTRODUCTION

It is becoming increasingly apparent that many modern imaging systems would greatly benefit from a new type of electrical to optical transducer which differs markedly from the conventional high-vacuum display. This new imaging device should be capable of being constructed with a screen area that is many times that of a conventional CRT and it should have overall external dimensions which approximate a thin panel. Among the important operational requirements for the improved display are high brightness, good resolution, fast scanning, accurately controlled halftones, and flexible storage capabilities for minimum flicker.

Recent progress in the development of bright and efficient electroluminescent phosphors has encouraged attempts to build a solid-state display screen.[1] The back electrode on an electroluminescent panel can be composed of a plurality of separate isolated areas which define the "elements" of the multielement display. A high resolution image can be formed on this electroluminescent panel if a carefully defined pattern of excitation is applied to these elements. The major problems which must be solved lie primarily in the manner by which this excitation is distributed to and maintained on the screen.

An early suggestion was that an electroluminescent television display might consist of a phosphor sandwiched between an array of mutually perpendicular conducting strips in a matrix form.[2] It was proposed that excitation should be switched sequentially to the various rows and columns of the array in order to scan this screen. Careful study of the properties of intrinsic electroluminescence has shown that this approach is not feasible. Excitation must be applied simultaneously and continuously to the elements of an electroluminescent panel, rather than in short pulses, in order to achieve a bright, flicker-free image. The process of providing this mode of continuous excitation is here called storage.

One method of building storage into the electroluminescent screen is to incorporate a photoconductive structure which regulates the amount of excitation applied to the electroluminescent panel.[3,4] Light feedback is permitted between the electroluminescent and photoconductive areas so that the elements of the screen function in a bistable manner. An image is formed by optically triggering various elements of the array from the dark to the lighted state. Some means must be associated with the screen in order to transform from an electrical video input to the optical triggering signals.

The photoconductive-electroluminescent screen fails to meet the requirements set forth for the modern display device, in that scanning speeds are severely limited by the sluggish response of the photoconductors. In addition, continuous halftones are not generally obtained since the elements are bistable or, at best, multistable. Finally, the elements, once they are triggered "on," cannot be individually erased, and power must be removed from a large section of the screen in order that new information may be applied.

A ferromagnetic control structure may also be used to apportion the excitation to the electroluminescent screen. There are several modes in which such a screen might be operated. The phenomenon of ferroresonance may be utilized in order that the elements be bistable.[5] Alternately, the ferromagnetic structure may control the excitation applied to the electroluminescent elements in a continuous manner in accordance with control currents of fluxes established by a signal distribution system. In either case, the major disadvantage to this approach appears to be the physical realization of the control structure. The fabrication of, for example, 250,000 separate and noninteracting inductors on the back of an electroluminescent TV screen would indeed appear to be a formidable problem.

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* Original manuscript received by the IRE, April 2, 1958. Reprinted from 1958 IRE NATIONAL CONVENTION RECORD, pt. 3, pp. 31–39.

† Westinghouse Electric Corp., Pittsburgh, Pa.

[1] G. Destrian and H. F. Ivey, "Electroluminescence and related topics," PROC. IRE, vol. 43, pp. 1911–1940; December, 1955.

[2] W. W. Piper, "Phosphor Screen," U. S. Patent 2,698,915, filed April 28, 1953, issued January 4, 1955.

[3] R. K. Orthuber and L. R. Ullery, "Solid state image intensifier," *J. Opt. Soc. Amer.*, vol. 44, pp. 297–299; April, 1955.

[4] E. E. Loebner, "Opto-electronic devices and networks," PROC. IRE, vol. 43, pp. 1897–1906; December, 1955.

[5] J. J. Stoker, "Nonlinear Vibrations in Mechanical and Electrical Systems," Interscience Publishers, Inc., New York, N. Y., p. 17; 1950.

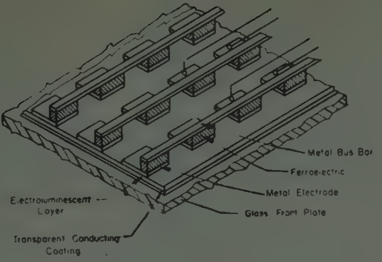

Fig. 1—Simple ELF array.

A much more desirable means of building storage into the electroluminescent screen is to use ferroelectric control. The ferroelectric material is utilized for its nonlinear capacitance characteristics. The excitation applied to each point on the electroluminescent panel is determined by the capacitance of the associated portion of the ferroelectric control structure. This capacitance is, in turn, altered by a charge pattern distributed over the screen. Since the ferroelectric has a high dielectric resistivity, the control charge pattern, and hence the image on the electroluminescent panel, remains constant until it is purposely modified.

This type of solid-state display, called here an ELF screen, offers simultaneous solutions to the problems of brightness control and storage. The ferroelectric layers are well-matched in impedance to the electroluminescent layers and it is believed that large area, high resolution screens no more than a fraction of an inch thick can be fabricated by relatively simple electroding techniques. High contrast ratios and extremely flexible storage are obtained with moderate excitation requirements.

## FERROELECTRIC CONTROL

The ELF screen may be considered to be a configuration of electroluminescent and ferroelectric capacitors. Fig. 1 illustrates *schematically* one way in which they might be arranged in a multielement array. In a more practical screen configuration the "elements" may actually be defined by the electrode configuration on a ferroelectric-electroluminescent laminate and may be scarcely recognizable as separate entities. Regardless of the actual form of the screen however, the functions of the materials are always the same. The electroluminescent cell emits light in accordance with the ac potential appearing across it, while the ferroelectric body causes this potential to be altered in accordance with the applied video control potential.

The electroluminescence utilized in the ELF screen is of the intrinsic type. Intrinsic electroluminescent cells generally consist of a phosphor powder embedded in an insulator and emit light only under the action of a changing electric field. Sustained emission does not result from application of a constant field nor does a constant field particularly affect the light output under alternating excitation.

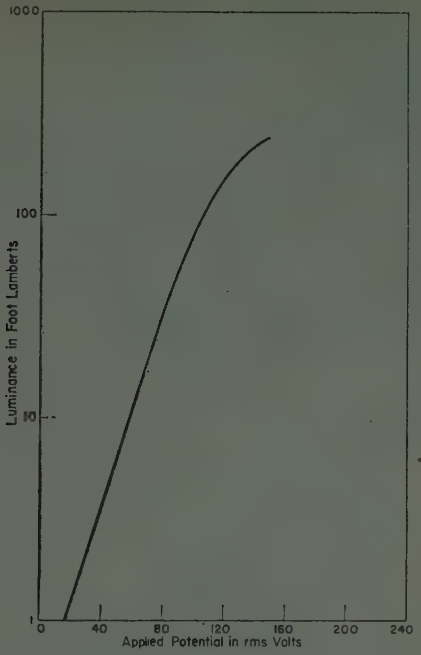

Fig. 2—Luminance of a Westinghouse electroluminescent cell as a function of voltage.

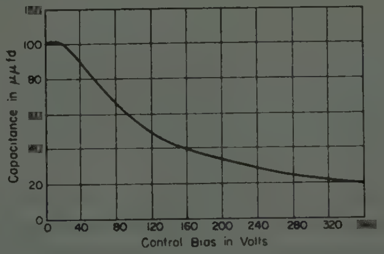

Fig. 3—Small signal capacitance of a ferroelectric capacitor as a function of control bias.

Fig. 2 describes the average brightness of a typical cell as a function of the amplitude of the 10-kc excitation. It is important to note that the brightness varies very rapidly with voltage, changing by as much as 140/1 for a 5/1 change in excitation amplitude.

The ferroelectric use in the ELF screen is the ceramic form of barium strontium titanate. In this application, the property of this material which is of primary interest is its voltage sensitivity when used as a dielectric.[6] Unlike ordinary capacitors whose capacitance is relatively independent of voltage, the effective capacitance of a ferroelectric is a function of the applied bias voltage or charge. Fig. 3 shows this behavior for a sample ceramic with planar electrodes.

It should be emphasized that this curve illustrates the small signal behavior of the ceramic and may not be used to compute the behavior of circuits in which relatively large ac potentials are present. Large signal calculations should be based on the instantaneous charge vs voltage characteristics of the ferroelectric,

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[6] G. W. Penney, J. R. Horsh, and E. A. Sack, "Dielectric amplifiers," *Trans. AIEE*, vol. 72, pt. 1, pp. 68–79; March, 1953.

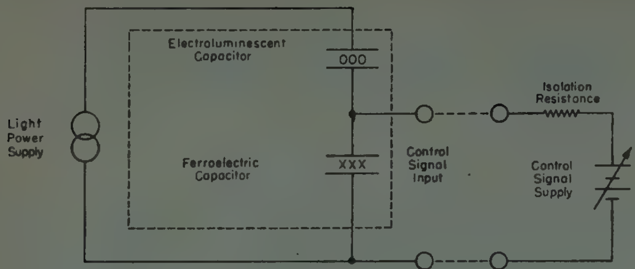

Electroluminescent Capacitor
000
Isolation Resistance
Light Power Supply
Ferroelectric Capacitor
XXX
Control Signal Input
Control Signal Supply

Fig. 4—Equivalent circuit of the two component ELF element.

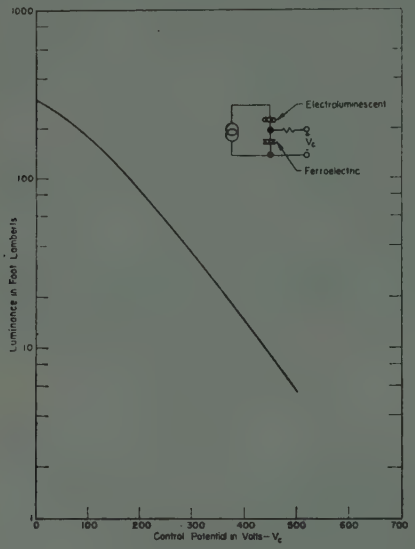
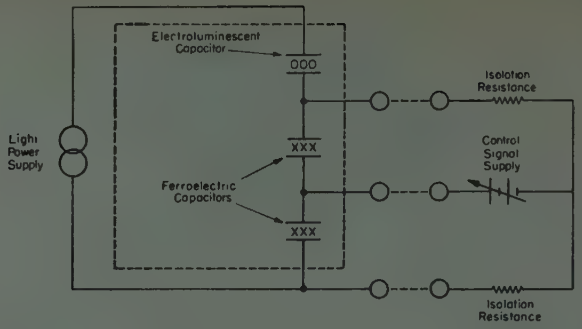


Fig. 5—Control curve for a two component ELF element.


Electroluminescent Capacitor
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Isolation Resistance
Light Power Supply
XXX
Control Signal Supply
Ferroelectric Capacitors
XXX
Isolation Resistance

Fig. 6—Equivalent circuit of a three component ELF element.

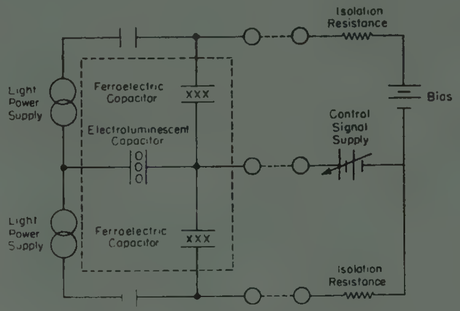
Isolation Resistance
Bias
Light Power Supply
Ferroelectric Capacitor
XXX
Control Signal Supply
Electroluminescent Capacitor
Light Power Supply
Ferroelectric Capacitor
XXX
Isolation Resistance

Fig. 7—Equivalent circuit of a bridge configuration.

which are often called dynamic hysteresis loops. In qualitative considerations of circuit performance, however, it is convenient to consider the ferroelectric capacitor as an element whose effective reactance increases with bias.

Although in the actual screen laminate it may be difficult to observe a specific circuit arrangement for each element, it is convenient to think in terms of an equivalent circuit for the element in considering the operation of the screen. Actually, there are a number of different element configurations in which the ferroelectric components can exert the proper influence on the excitation applied to the electroluminescent component. Each has certain advantages and disadvantages. The simplest arrangement is the series configuration of Fig. 4. An electroluminescent and a ferroelectric capacitor are connected in series with an ac source which is called the light power supply. Typically this source might be 200 volts rms, 10,000 cps. In addition, provision is made for the introduction of a control potential. This is a unidirectional charge or voltage which, for purposes of explanation, might be supplied by a battery in series with an isolation resistance.

Assume that the components in Fig. 4 are proportioned so that with no control potential applied, the ac potentials on the electroluminescent and ferroelectric cells are 150 and 50 volts, respectively. This corresponds to the "full-on" or bright condition for the element. If the control potential is now increased from zero, the capacitance of the ferroelectric body decreases. A larger fraction of the light power voltage appears across the ferroelectric and a smaller fraction across the electroluminescent cell. When the control potential reaches 500 volts dc, the ac across the electroluminescent cell would be reduced to, perhaps, 50 volts. This is the "off" or dark condition for the element.

From Fig. 2 it can be seen that dropping the excitation on the electroluminescent cell from 150 to 50 volts rms causes the brightness of the cell to diminish from 243 to 6.1 foot-lamberts for a luminance ratio of nearly 40/1. As shown in Fig. 5, the luminance can be set at any level in this range by the corresponding value of control potential or charge. If, after a control potential is established on the capacitors, the control supply is disconnected, the control charge is trapped and causes the element to continue to emit at the pre-set brightness level. This is the storage feature of the screen. Storage time is primarily determined by ohmic leakage.

A three-component ELF screen element is shown in Fig. 6. In this circuit, the ferroelectric capacitors represent a larger fraction of the total ac-loop impedance and therefore can exercise greater control over the excitation appearing across the electroluminescent cell. In addition, since the control potential does not appear across the electroluminescent capacitor, the restrictions imposed by the relatively low breakdown strength of this component are considerably relaxed.

A bridge-circuit element configuration is presented in Fig. 7. The control potential is applied to the ferroelectric capacitors to cause the capacitance of one to increase while the other decreases. This alters the un-

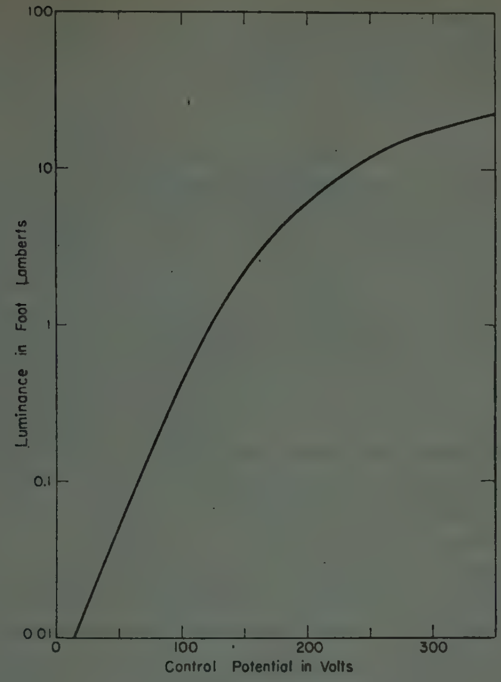

Fig. 8—Control curve for a bridge ELF element.

balance of the bridge and varies the excitation applied to the electroluminescent cell. Fig. 8 shows a control curve for an experimental single-element bridge configuration.

The dotted boxes in Figs. 4, 6, and 7 include the components which constitute an individual element of the multielement array. The isolation resistances and the light-power, bias, and control signal supplies, are usually common to the entire array. The actual arrangement of the components in a screen element may vary markedly from that shown in the equivalent circuits in order to adapt the element to the electrical and mechanical constraints of the structure.

Using the three component and bridge configurations, model screens have been built which show single element "on" to "off" luminance ratios of over 100/1 with control potentials as low as 200 volts. Constrast ratios between adjacent light and dark areas of over 50/1 have been measured for multielement screens. Typical highlight luminance for these screens is on the order of 25 foot-lamberts and storage times of up to several minutes are achieved in models built to date.

## Screen Structure

The exact physical form of the ELF screen depends upon the element configuration and the details of the signal distribution system. A prime requirement of the structure, of course, is that the large number of elements which are required be formed by simple mechanized techniques.

The multielement electroluminescent panel can be fabricated by vacuum evaporating the metallic back electrode through a suitable mask. Excitation may be applied to any electrode in the resulting mosaic without significant electrical interaction with its neighbors.

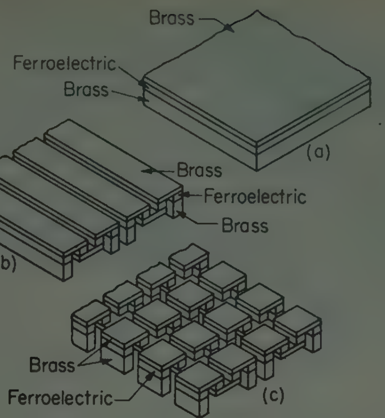

Fig. 9—Formation of a ferroelectric control structure from a metal-ceramic-metal sandwich.

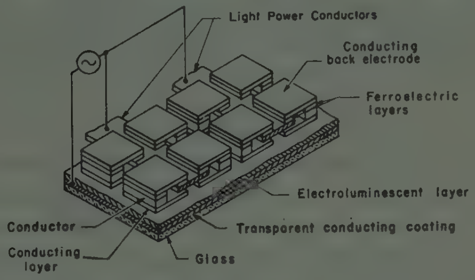

Fig. 10—ELF screen structure using the control array of Fig. 9(c).

There are a number of ways in which the ferroelectric structure can be provided. An early approach was to start with a metal-ferroelectric-metal sandwich as in Fig. 9(a). Special techniques have been developed by which sheets of brass may be intimately bonded to flat wafers of the ferroelectric ceramic. The composite slab is then slotted by a multiple cutter machining technique as in Fig. 9(b) and 9(c) to form the control array which, in turn, is fastened to the electroded electroluminescent panel as shown in Fig. 10. Each element of this ELF screen has the equivalent circuit form of Fig. 6. The entire array is encapsulated to eliminate sparkover and increase mechanical stability.

A preferred method of construction is illustrated by Fig. 11. The structure may be thought of as a laminate of three separate layers. The first is the electroluminescent dielectric on which is deposited a mosaic of electrodes. Next, there is an insulating interface which contains a spaced array of conductors. The top layer of the laminate is a specially electroded ferroelectric ceramic sheet. The control structure is formed by the electrode arrangement.

Fig. 11 presents a laminate structure in which each element has the equivalent circuit of Fig. 6. Similar laminates have been designed for other element configurations. A very desirable feature of this approach is that the conductors and many of the components required for the signal distribution system can be formed as an integral part of the screen structure.

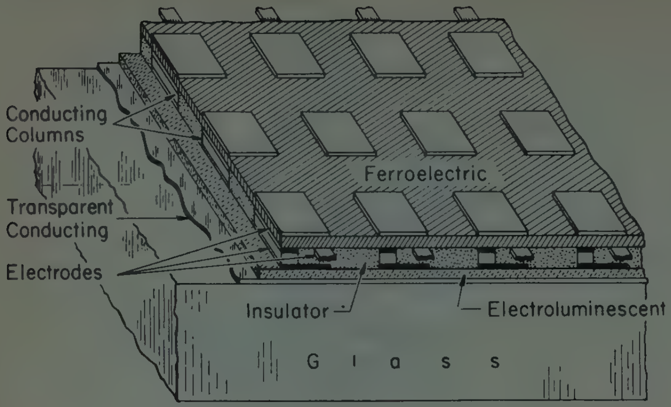

Fig. 11—Laminate form ELF structure.

With the cutting technique, screens have been built with from 4 to 10 elements per inch. The laminate approach should provide a significant increase in resolution.

## SIGNAL DISTRIBUTION

The various methods for forming an image on an ELF display may be summarized in three broad categories. The first is typified by the use of an electron beam to effect the generation of the control charge pattern. The second includes those approaches in which the distribution is accomplished by means of radiation principally, though not necessarily, in the optical range. The third category includes systems in which the control charge pattern is established without direct recourse to electron scanning or optical means. This last category, for want of a more descriptive term, is called "ohmic."

The ELF screen may be scanned in a predetermined pattern or the image may be constructed at random as information for various points becomes available. The latter case might be encountered where the image information comes from a computer. The ELF screen is excellent for such application because of its storage flexibility.

## OHMIC DISTRIBUTION

Present indications are that ohmic distribution will most closely satisfy dimensional restrictions imposed by the majority of the potential applications of the ELF display. Only one distribution system of this type will be described; however, it should be emphasized that this system represents but one embodiment of a specific philosophy and there are many ohmic distribution philosophies.

Fig. 12 shows the major components of a system for scanning an ELF screen in a predetermined pattern. It is assumed that the video is available on a single input bus and that appropriate synchronizing signals are incorporated in the video to define lines and frames.

The video information for one scanning line of the screen is first distributed to a set of intermediate storage cells. There is one intermediate storage cell for each element of a scanning line. Once the video has been arranged on the intermediate storage cells the charge for an entire line is transferred simultaneously to the elements of that particular line.

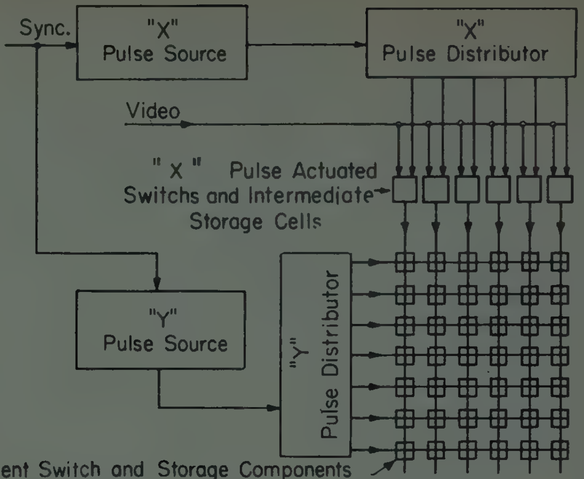

Fig. 12—Block diagram of an ohmic distribution system.

Considering the operation in greater detail, the $X$-pulse source in Fig. 12 supplies one synchronized pulse of proper shape to the $X$-pulse distributor for each line of video information. This pulse distributor, which might be a delay line, carries this pulse to each of its outputs in rotation. When the pulse appears at a given output, it excites the associated $X$-pulse actuated switch, say a diode, which closes momentarily to transfer the proper portion of the video signal to the associated intermediate storage cell.

Once the $X$ pulse has reached the last ouput of the distributor, charges which are indicative of the information in one video line have been stored in proper spacial accord on the intermediate storage cells which, in this case, could be capacitors. At this time, the $Y$-pulse source and $Y$-pulse distributor have cooperated to provide a pulse of proper waveform to the bus which traverses the line of the screen for which video information is now stored on the intermediate storage capacitors. This pulse causes the element pulse actuated switches for that line to open simultaneously. Charges are deposited directly on the ferroelectric control capacitors or, in an alternative approach, they are deposited on a separate set of capacitors connected to the ferroelectric components by decoupling resistors.

A system of this type has been tested and found to be quite feasible from a technical point of view. With this system video information may be distributed to the screen elements at megacycle rates.

The basic advantage of the intermediate storage philosophy is that the operating speed requirements on the element switches are greatly reduced. In an operating system, the intermediate storage is accomplished for half a line at a time. Hence, a half-line time rather than the scanning time for one element is available for transferring the control charges to the screen elements.

More sophisticated embodiments are conceivable in which several intermediate storage steps are included; these offer even greater relaxation of the speed requirements for the element switches.

### ELECTRON BEAM DISTRIBUTION

This distribution approach takes advantage of the inherent ease of scanning of an electron beam. The ELF screen is incorporated in a CRT envelope as shown in Fig. 13. A material having a secondary emission ratio greater than unity is deposited on the control electrodes and an electron collector screen is positioned behind the ELF array. If video is applied to the collector screen, the electron beam will bring each control electrode to the desired video potential as it scans the array.

There are a number of other ways in which the cathode-ray beam can be used to distribute control signals. For example, the beam can scan solid-state switches in which conductivity is induced by electron bombardment. These switches in turn commutate the video control signals to the ELF screen elements.

While distribution with an electron beam retains some of the disadvantages of the conventional CRT, it does provide a simple method for taking advantage of certain desirable features of the ELF array. The electron beam is relieved of the necessity of supplying the light power and instead acts only as a switching means. Consequently, the CRT accelerating voltage may be reduced. Since storage is inherent in the screen, a storage tube type of display can be achieved.

### OPTICAL DISTRIBUTION

If a photoconductor is associated with each element of the ELF screen there results a device which is potentially a very desirable image intensifier. The photoconductor adjusts the amount of control charge on the ferroelectric capacitors in accordance with the input light. The ferroelectric capacitors, in turn, vary the intensity of the output light. This device differs from the conventional photoconductive-electroluminescent image intensifier in that the ferroelectric constitutes a "gain stage" between the input and the output, and the photoconductor is relieved of the task of carrying the power required to excite the electroluminescent material. As a result, the ELF image intensifier can have considerably greater gain than the conventional intensifier and it may make use of faster photoconductors than are required for the latter device.

### DISCUSSION

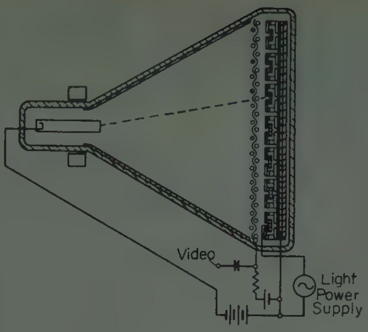

Fig. 13—Electron beam distribution.

The principle of operation of the ELF screen is well established. Models have been built which show single element "on" to "off" luminance ratios of over 100/1 with control potentials as low as 200 volts. Contrast ratios between adjacent light and dark areas of over 50/1 have been measured for multielement screens. The highlight luminances for these models have been on the order of 25 foot-lamberts. Storage times of several minutes are obtained under conditions of moderate humidity and there is reason to believe that improved encapsulation techniques will extend the storage period.

Early experimental ELF models have had resolutions of 4 to 10 elements per inch. However, experience with improved fabrication techniques indicates that it should be possible to double these figures in the near future. Eventually, resolution of 50 to 100 elements per inch or more may be attainable.

An ohmic distribution system has been tested and found to be quite feasible from a technical point of view. With this system, video information may be distributed to the screen elements at megacycle rates and it is believed that there is no technical barrier to the attainment of TV scanning speeds.

Single-element light amplifiers have been made in which photoconductors are used to set the control charge on the ELF elements. Tests show that these models have from 10 to 100 times the luminance gain of straight photoconductive-electroluminescent amplifiers using the same photoconductive materials.

### CONCLUSIONS

The ELF screen offers a fresh approach to the problem of large, flat screen imaging. By a very fortunate association of solid-state materials it provides high brightness, continuous halftones, flexible storage, and fast writing speeds.

As is the case with almost every multielement display, the main technical problems are associated with economical screen fabrication and feasible signal distribution means. With ELF, there is every reason to believe that these problems are surmountable.

### ACKNOWLEDGMENT

Many people have had a part in the development of the ELF display. In this paper the writer is acting as their spokesman.

Particular credit should be given to Dr. P. M. G. Toulon who has made significant contributions. A. E. Anderson, J. A. Asars, Dr. W. J. Harper, R. F. Hollandbeck, and Dr. P. N. Wolfe of the Westinghouse Research Laboratories staff have all been closely associated with the progress made to date.

# The Helitron Oscillator*

D. A. WATKINS†, FELLOW, IRE, AND G. WADA‡, MEMBER, IRE

***Summary*—A new type of voltage-tuned microwave oscillator, called the helitron, is described. This device is a practical example of E-type interaction. Electron focusing is accomplished by balancing centrifugal force against a radial electric field force and RF field interaction is both radial and angular. No magnetic field is required. The device employs a spirally-traveling electron beam interacting with the angular and radial components of RF field provided by an internal circuit structure. Experimental results include continuous voltage tuning from 1.2 to 2.4 kmc with an accompanying change in tuning voltage of from 650 to 1700 volts. Start-oscillation current is approximately 0.4 ma for a structure 4 inches long. Power output is in the vicinity of 1 to 10 milliwatts. Second-harmonic output is more than 25 db down, and all other spurious output is more than 60 db below the main oscillation. Possible advantages and limitations of the helitron are described together with brief mention of the accompanying theory of operation.**

## INTRODUCTION

IN the past few years, there have been numerous efforts on the part of various investigators to eliminate the magnet for beam focusing in traveling-wave and backward-wave tubes. The reasons for eliminating the magnet are fairly obvious: reduction in overall weight of the tube and absence of power supply for the magnet. Two examples of techniques not utilizing a magnet for beam focusing are periodic electrostatic focusing and Harris-flow focusing.[1]

The beam and circuit interaction of periodic electrostatic focusing is limited to O-type, *i.e.*, gain of the RF field is obtained by virtue of loss of kinetic energy of the electrons. To the present time, Harris flow has been used only with O-type traveling-wave and backward-wave tubes.

In contrast to O-type interaction, M-type, or crossed E-H field interaction, produces gain in circuit fields at the expense of decreased potential energy of the beam. In this type of interaction, synchronism between beam and field is maintained, yielding higher efficiency than is obtainable with O-type devices. Another feature of M-type interaction in backward-wave devices is the linear relation between frequency and beam voltage, whereas a square root relation applies in the O-type.

Another type of interaction having some similarity to M-type and involving focusing forces like that in Harris flow is embodied in an invention of H. Huber of C.S.F., Paris, France, in 1949. A simplified diagram of his idea is shown in Fig. 1, where the circuit on the inside is at a potential which is positive with respect to the outer conductor. To show that this tube results in a type of interaction similar to M-type interaction, consider first that, for a circular orbit, there is only one equilibrium velocity, which is a function of the circuit (inner cylinder) to sole (outer cylinder) voltage. Here it is assumed that the sole and cathode are at the same potential. When an electron interacts with the circuit to give energy to the circuit RF field, it will slow down and then move closer to the circuit since the static electric field force will be greater than the centrifugal force. The electron will then have a slightly smaller equilibrium radius and a correspondingly higher angular velocity. It can now further interact with the circuit RF field in approximate synchronism with it and this process may continue until the electron is intercepted by the circuit. Devices using this type of interaction in conjunction with electrostatic focusing have been designated E-type by Heffner and Watkins.[2]

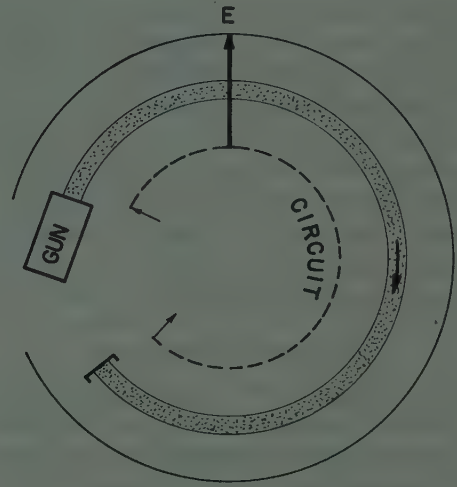

Fig. 1—Simplified pictorial drawing of Huber's device. Focusing is accomplished by balancing the centrifugal and electrical field forces.

Versnel and Jonker[3] have proposed a tube utilizing E-type interaction as a "Magnetless Magnetron" oscillator. Huber's proposal, as well as that of Versnel and Jonker, considered many electronic wavelengths for one revolution of the beam. Heffner and Watkins[2] have shown that to obtain stiffness of focusing comparable

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‡ Watkins-Johnson Co., Palo Alto, Calif.

[1] L. A. Harris, "Axially symmetric electron beam and magnetic-field systems," PROC. IRE, vol. 40, pp. 700–708; June, 1952.

[2] H. Heffner and D. A. Watkins, "The practicality of E-type traveling wave devices," PROC. IRE, vol. 43, pp. 1007–1008; August, 1955.

[3] A. Versnel and J. L. H. Jonker, "A magnetless magnetron," *Philips Res. Reps.*, vol. 9, pp. 458–459; December, 1954.

with M-type or O-type devices, the number of electronic wavelengths per revolution should be on the order of the square root of two in the E-type tube. A possible way to accomplish this result is to have the beam make many revolutions and limit the number of electronic wavelengths per revolution to the order of the square root of two.

The foregoing is the basic idea of the helitron, conceived by Watkins in 1954. This device is shown schematically in Fig. 2. The tube can be visualized by considering a beam of electrons traveling in a helical path. This path encircles a four-conductor transmission line which is the circuit. Outside the beam, and concentric with the circuit, is the sole. A dc voltage applied between the circuit and sole produces a radial electrostatic field which balances the centrifugal force on the electrons. The RF interaction is between the electrons and the angular and radial components of the circuit RF field.

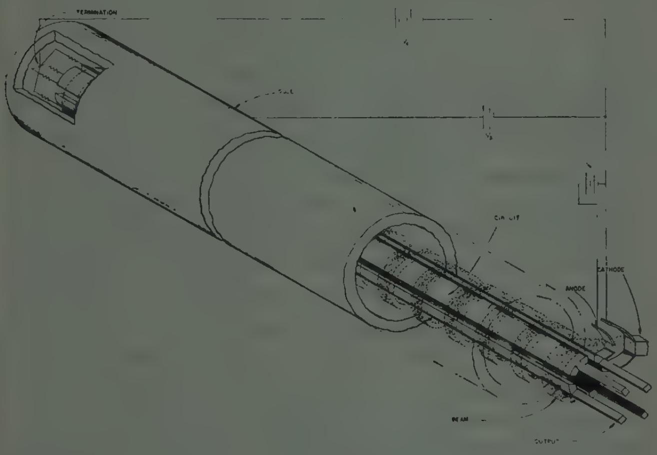

Fig. 2—Pictorial diagram of the helitron oscillator. The beam travels in a helical path interacting with the angular and radial field components of a TEM wave on the circuit.

The helitron should be distinguished from the Russian "spiratron,"[4] which is similar in name and in beam configuration. In the spiratron, the RF interaction involves only the axial component of the circuit RF field and not the angular component. In other words, the spiratron is a Harris-flow-focused O-type forward-wave amplifier with a means of launching the beam similar to that used in the helitron. The helitron is an E-type backward-wave oscillator or amplifier.

In theory, the helitron principle could be employed either in a forward or backward-wave amplifier or oscillator. This report will be concerned with operation as a backward-wave device. For backward-wave interaction, a TEM wave can be imagined to travel from the collector toward the gun (see Fig. 2). The beam will interact with this TEM wave when the frequency is such that in passing from one circuit gap to the next, it "sees" the same phase of the RF field. The electrons may be thought of as interacting with a helical space-harmonic of the RF field.

The RF mode of excitation on the four-conductor circuit is plus, minus, plus, and minus. This mode will then present approximately two electronic wavelengths per revolution. The original thought was to use a two-conductor circuit, hence one electronic wavelength per revolution, but this was later changed to a four-conductor circuit to make the structure larger. For a given beam voltage and frequency, the four-conductor circuit will be twice as large as a two-conductor circuit.

The first theoretical study of the helitron was patterned after an analysis of crossed-field devices by Pierce,[5] and revealed that the allowed propagation constants were almost identical to those of M-type tubes. Based upon this analysis, a design of a backward-wave oscillator was formulated and design dimensions were obtained.

A successful helitron oscillator was built and tested. It was found that various experimental data did not agree or were not predicted by the aforementioned theory. Because of this, various idealized models were analyzed in order to understand and predict the behavior of the helitron. None of the analyses has been completely successful.

This paper emphasizes the experimental results obtained with the helitron. The analyses studied to explain the behavior of the device discussed briefly.

## DESCRIPTION OF THE HELITRON OSCILLATOR

This section describes the mechanical details of a laboratory model of the helitron oscillator. It is to be noted that a practical tube of this type would not be as large or as complicated as the laboratory model.

Fig. 3 illustrates the top and side views of the completed tube. As viewed in the figure, there are two rods on either side of the tube proper which serve to align and support the structure. On both ends of the rods are brazed kovar rings to hold the end seals of the tube. The end seals perform the functions of holding and aligning the circuit and providing for external connection to the circuit. The inner portions of the end seals consist of a glass section through which four kovar pins are sealed. Inside the tube, the circuit pieces are held in alignment by the pins. Outside, the pins are connected either to terminating resistors or output coaxial cables.

The ends of the terminating resistors are connected to a brass end cover which forms an RF choke so that the sole and the ends of the resistors are at the same RF potential. On the collector end each circuit piece is terminated by a resistor, and on the gun end, three of the circuit pieces are similarly terminated. The fourth

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[4] The spiratron was first described by F. S. Tchernov at the Congrès Internationale Tubes Hyperfrequences, Paris, France, May, 1956.

[5] J. R. Pierce, "Traveling-Wave Tubes," D. Van Nostrand Co., Inc., New York, N. Y., chs. 13 and 15; 1950.

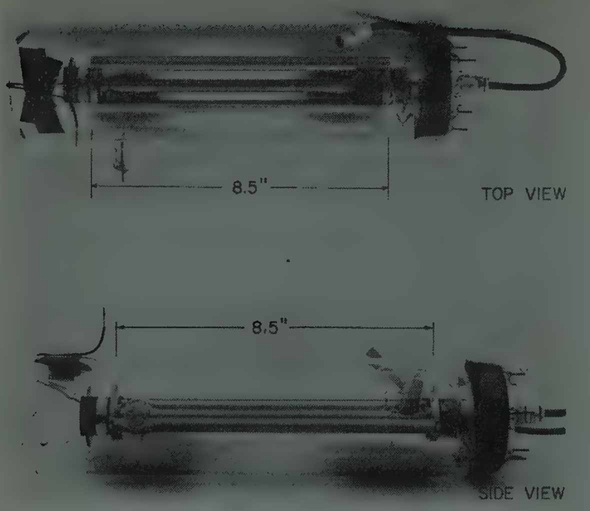

Fig. 3—Top and side views of the experimental helitron oscillator.

circuit piece on the gun end is connected to the center conductor of the output coaxial cable. The outer shield of the coaxial line is connected to the end cover which also functions as a choke on the gun end.

The four circuit pieces were formed from 0.020-inch-thick cross-rolled molybdenum sheet. The outside diameter of the circuit structure was 0.150 inch. Molybdenum spacers between opposite circuit pieces were brazed one inch apart. The spacers were alternately located on each set of circuit pieces so that the distance between the spacers was one-half inch. The main function of the spacers was to strap out undesired modes on the circuit. Sapphire rods were placed between the circuit segments to provide mechanical rigidity of the structure and maintain the relative orientation between the circuit pieces. The total length of the circuit was approximately eight inches.

The sole was formed from 0.030-inch-thick cross-rolled molybdenum sheet; it was made in two half-sections to facilitate fabrication. The inner radius of the sole was 0.156 inch. The sole pieces were mounted to the tube by shoulders on the end seals.

Two collectors were employed. One was a blade at the end of the sole and the second was an insulated square segment of the sole located approximately halfway along the sole.

The electron gun assembly was mounted on one of the sole-halves. The gun is seen in Fig. 3 as the protuberance. Based upon design criteria for backward-wave oscillations of the helitron, the beam was chosen to have a cross section of $0.016 \times 0.079$ inch with a current of 16 ma at 1000 volts. To obtain this beam, it was decided to use convergent flow in one dimension and parallel flow in the other dimension. The gun used a Type-A Philips cathode, with a molybdenum focus electrode assembly. The anode snout and cylinder were made of stainless steel. The end of the snout corresponded to the position of minimum beam thickness. The opening of the snout was $0.030 \times 0.100$ inch.

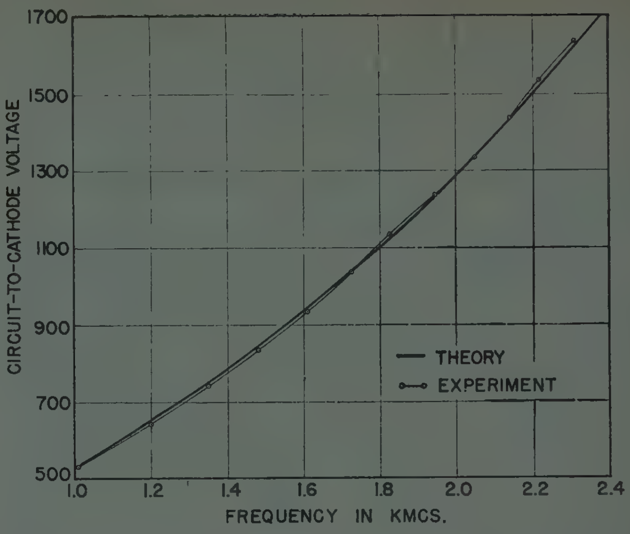

Fig. 4—Experimental and theoretical tuning curves for either full- or half-length interaction. The data are for $V_a = 375$ volts, and $I_{coll}$ varied from 0.45 to 1.0 ma.

## Experimental Results

The experimental data presented were taken from two models of the helitron. The models differed; one of them had a constricted anode snout in an attempt to obtain a thinner beam. No significant change in performance was gained by this modification. Since the data for starting current and spurious oscillations were taken with this constriction in place, the range of operation was limited by beam interception in the anode.

All data were taken with a sole-to-cathode voltage of 135 volts. This choice resulted in the broadest tuning range for the range of circuit-to-cathode voltages used. No magnetic shield was employed on the tube. Simple calculations indicated that for the range of circuit-to-cathode voltages used, the ratio of magnetic to centrifugal force is very small for the usual stray magnetic fields. The beam could be collected either at the first or second collector. These two possibilities are designated half- or full-length operation.

The tuning curve for half- or full-length is shown in Fig. 4. The curve is limited at low voltages owing to sudden drop in beam transmission, and at the high-voltage end the curve is discontinuous because of the voltage breakdown of the insulator in the RF choke assembly. The theoretical tuning curve is also drawn in this figure; note that agreement between the two curves is excellent. The derivation of the theoretical tuning curve is given in the Appendix.

Fig. 5 depicts starting current for oscillation as a function of frequency. Current control was obtained by varying the anode voltage. It is noticed that the curves are labeled first and second oscillation. For a given circuit-to-cathode voltage, the tube breaks into oscillation when the beam current is raised to a critical value, *i.e.*, the starting current. This point corresponds to the first oscillation curve. As the current is further increased, the first oscillation frequency is present until the second

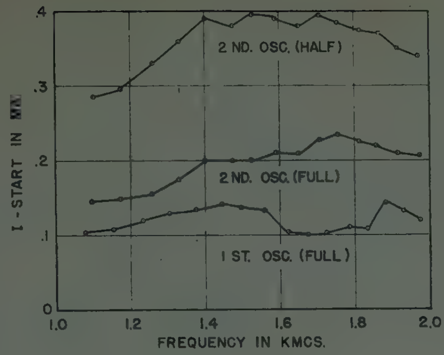

Fig. 5—Starting current for oscillation as a function of frequency for full- and half-length. For a fixed voltage, signal is first observed at a current corresponding to the first oscillation curve. Further increase in current produces no change in signal frequency until the second oscillation curve is reached. At this point, the signal jumps to a slightly higher frequency and remains there with further increase in current.

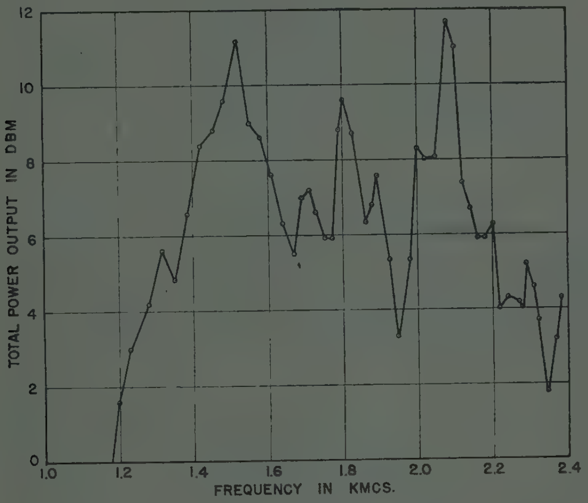

Fig. 6—Total obtainable power output as a function of frequency. Data are for $V_a = 375$ volts and $I_{coll}$ varied from 0.45 to 1.0 ma.

oscillation curve is reached, at which time the frequency suddenly jumps to a slightly higher value. Further increase of current gives only the second oscillation frequency. For the tube operating half-length, only the second oscillation is obtained. For this case, there was no definite oscillation at the expected first oscillation frequency. It should be noted that the value of the current for the second oscillation, half-length, is approximately twice that of the second oscillation, full-length. The jump in frequency from first to second oscillation varied from 20 mc at the low end to 45 mc at the high end of the tuning range.

Measurements of starting current with open and short-circuit terminations at the collector indicated a high degree of insensitivity to load variations as in the O-type backward-wave oscillator.

Fig. 6 shows power output over the tuning range. Data for this curve were obtained by varying only the circuit-to-cathode voltage. As pointed out in the section on the description of the helitron, output is taken off only one circuit piece. Six db have been added to the measured power to include the power delivered to the three load resistors.

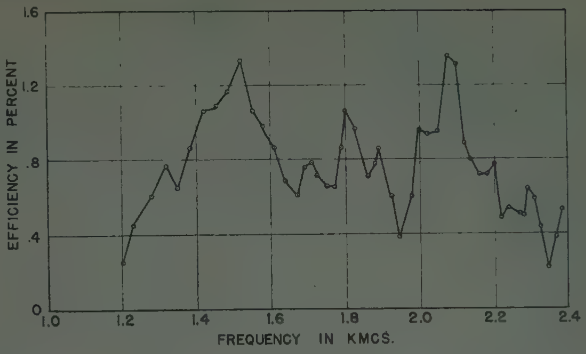

Fig. 7—Efficiency as a function of frequency. DC input power is defined as collector current times circuit voltage. The power output corresponds to the data of Fig. 6.

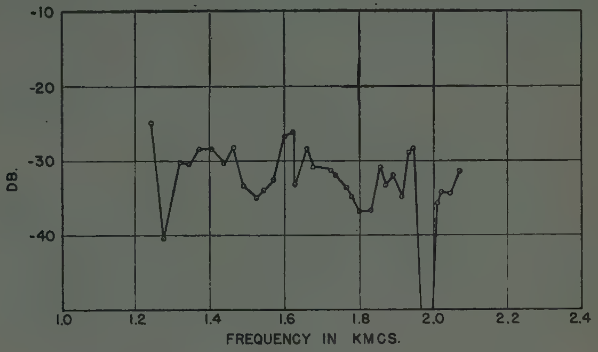

Fig. 8—Magnitude of second-harmonic output relative to fundamental output as a function of frequency.

Efficiency of this tube is presented in Fig. 7 and is based upon input power equal to collector current times circuit-to-cathode voltage. It is thought the efficiency can be increased by better beam control. Fig. 8 shows the magnitude of the second harmonic relative to the main signal. Theoretically, for a pure balanced mode, the circuit cannot support even-numbered space harmonics; however, minor discontinuities, such as the gun snout, will introduce them.

Fig. 9 gives the beam transmission over the tuning range. Beam transmission is defined as the ratio of current collected to current projected into the RF interaction region. The drop in transmission at higher frequencies is due to the decreasing equilibrium radius with a resultant increase in circuit interception.

An important experimental result, with regard to application, is related to the relative level of spurious oscillations at half- and at full-length. Spurious oscillation is defined here as any unwanted output present with the main signal except the second harmonic. These data are cited in Fig. 10, where the lower two curves, labeled *A* and *B*, represent comparable conditions; *i.e.*, at 1.4 kmc the collector current was adjusted to be 1.3 times the second oscillation starting current by variation of anode voltage. The uppermost curve, labeled *C*, represents switching from half-length (curve *A*) to full-

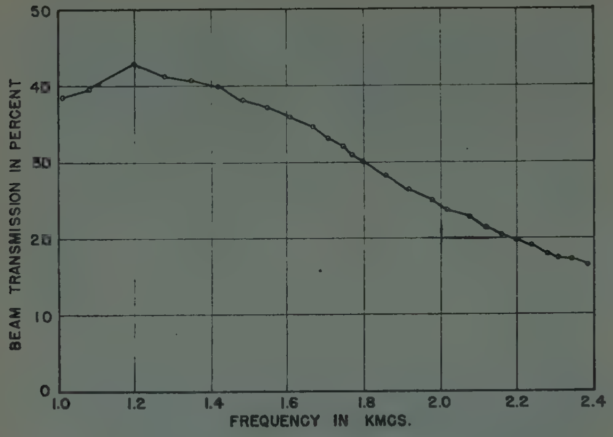

Fig. 9—Beam transmission vs frequency. Beam transmission is defined as the ratio of collector current to the current projected into the interaction region.

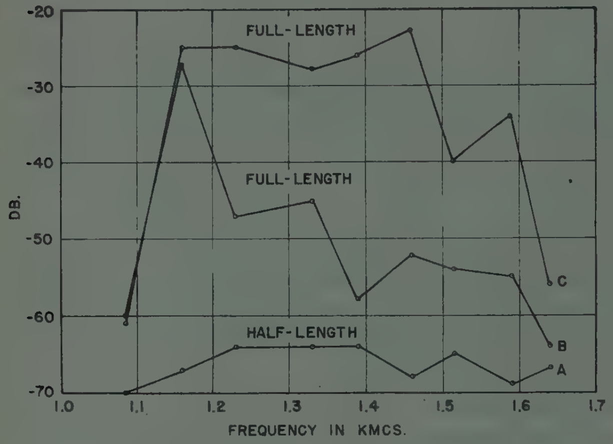

Fig. 10—Spurious oscillation level relative to main signal level vs frequency for full- and half-length. Current was adjusted for curves *A* and *B* to be 1.3 times second oscillation starting current at 1.4 kmc. Curve *C* represents switching from half-length (curve *A*) to full-length with no change in voltages.

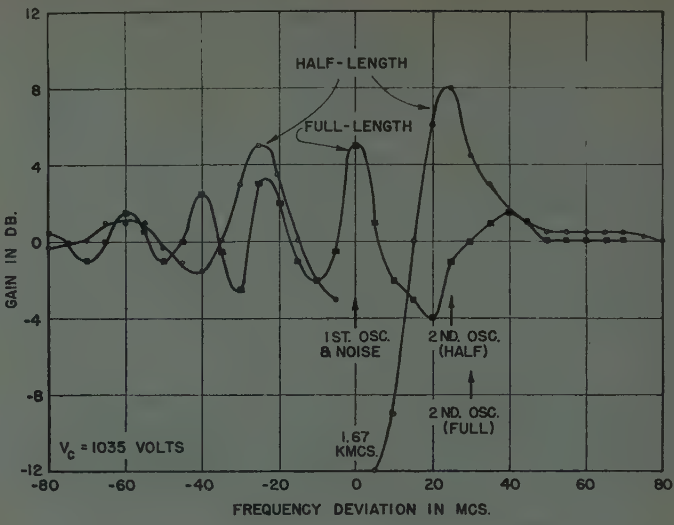

Fig. 11—Backward-wave gain as a function of input frequency. Input frequency is expressed as its deviation from 1.67 kmc. Zero mc corresponds to the first oscillation frequency for full-length. The second oscillation frequency for half-length corresponds to 25 mc and the second oscillation frequency for full-length corresponds to 30 mc. The current for half-length was 0.86 times the second oscillation starting condition and, for full-length, 0.9 times the first oscillation starting condition.

length with no change in anode voltage. Notice that for half-length the spurious is always more than 60 db below the main signal, whereas for full-length the spurious is only 25 db down. At the time of this writing, another modification has been made in the laboratory tube to provide operation at one-quarter length. Tests will be performed on this tube regarding the spurious oscillation characteristics.

Backward-wave amplifier gain is illustrated in Fig. 11. The data were obtained by keeping all voltages and currents constant while observing gain for various input frequencies. Two curves are seen in the figure; one for full-length and the other for half-length. For full-length, the current was 0.9 of the first oscillation starting current, and for half-length the current was 0.86 of the second-oscillation condition. There is a discontinuity in the region of zero-mc deviation for half-length because at this position the amplified noise was so large that receiver readings were rendered unreliable. In Fig. 11 zero-mc deviation corresponds to the frequency of first oscillation for full-length. The amplified noise, which was at the same frequency for full- and half-length, is shown at the same frequency as the first oscillation but this frequency varied depending on the circuit-to-cathode voltage. The position marked second oscillation (half) corresponds to the frequency where oscillation occurred for half-length. Second oscillation (full) corresponds to the frequency for which the jump from first to second oscillation for the full-length case occurred.

## ANALYSES STUDIED TO EXPLAIN THE OPERATION OF THE HELITRON

Various idealized models were studied to explain the operation of the helitron; none of them was completely successful. The analyses did not predict the experimentally obtained low starting current for oscillation nor the backward-wave gain characteristics. For example, the starting current obtained from these analyses was about fifty times greater than that observed experimentally.

The first analysis was patterned after Pierce[5] and indicated that the allowed propagation constants were almost identical to those of M-type tubes. The analysis was therefore modified by using Gould's[6] result to obtain a first-order correction to include the effect of space charge. Using the value of current at start oscillation as experimentally observed, the space charge was theoretically too small to cause any appreciable reduction in starting current. The second analysis considered the effect of circuit mismatch, and showed that the starting current would have a sinusoidal variation due to reflections. The third analysis treated the effect of adjacent turns of the beam, and the result was to increase the plasma wave number as compared with the single beam. The fourth analysis considered the additional forward-wave mode since there was some correlation between the second oscillation and forward-wave frequencies. The additional mode caused very little perturbation on the original solution. The fifth and last analysis dealt with a beam having a dc velocity spread. Interference in the beam due to such a spread might produce the experimentally observed backward-wave gain characteristics. This analysis was not completed because of the many allowed values of propagation constant which it yielded.

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[6] R. W. Gould, "Space-charge effects in beam type magnetrons," *J. Appl. Phys.*, vol. 28, pp. 599–605; May, 1957.

## CONCLUSIONS

A successful helitron oscillator has been built and tested. The principal features of this tube are two fold; no magnet is needed for beam focusing, but beam-to-circuit interaction is like that in the M-type. Elimination of the focusing magnet results in reduction in weight and increase in over-all efficiency of the tube. E-type interaction offers the possibility of higher efficiencies.

The helitron is not thought to be a high-power device. It is limited to perhaps 100 milliwatts at *X* band because the circuit must be internal to the beam, making cooling difficult.

The experimental results indicate that the device is a promising competitor to existing voltage-tuned microwave oscillators. The tube tunes continuously: a three-to-one change in circuit-to-cathode voltage produces a two-to-one change in oscillation frequency. This characteristic lies between that of O and M-type oscillators. The level of spurious oscillation for the helitron should be as good as that in other voltage-tuned oscillators. The starting current is found to be inversely proportional to interaction length, hence it is possible to build a small and compact oscillator and yet remain in the realm of realizable beam currents. Elimination of the usual focusing magnet results in a lightweight device and also contributes to its compactness.

## APPENDIX: TUNING CURVE

The assumptions are: no space charge and equilibrium radius of the electron trajectory. In Fig. 2, the potential and field between the sole and circuit, neglecting circuit gaps, is

$$V = V_s + (V_c - V_s)\frac{\ln s/r}{\ln s/c}, \tag{1}$$

$$E_r = \frac{V_c - V_s}{r \ln s/c}, \tag{2}$$

where

$s$ = sole radius,
$c$ = circuit radius,
$V_c$ = circuit-to-cathode voltage.
$V_s$ = sole-to-cathode voltage.

The equilibrium velocity is given by

$$v_{\theta e}^2 = -\frac{\eta(V_c - V_s)}{\ln s/c}, \tag{3}$$

where $\eta$ = charge-to-mass ratio of an electron and $\eta < 0$. The electron accelerating potential will be assumed to be dependent upon (1) and not on the anode voltage. Therefore, the total velocity is

$$v_t^2 = -2\eta V. \tag{4}$$

Since the beam is injected at an angle, for helical motion, $v_t$ will be composed of two parts, $v_\theta$ and $v_z$, and will be governed by

$$v_t^2 = v_\theta^2 \sec^2 \phi \tag{5}$$

$$\phi = \text{beam pitch angle.}$$

Substituting (1) into (4) and equating the result to (5) gives the equilibrium radius when $v_\theta = v_{\theta e}$.

$$r_0 = s e^{-\sec^2 \phi/2} = \left(\frac{c}{s}\right)^{V_s/V_c - V_s}. \tag{6}$$

For interaction, the transit time of the electron should be very close to a half-cycle. Using (3) and (6), for the frequency relation one obtains

$$f \simeq \frac{1}{\pi s}\sqrt{-\frac{\eta(V_c - V_s)}{\ln s/c}}\, e^{\sec^2 \phi/2}\left(\frac{c}{s}\right)^{V_s/V_c - V_s}. \tag{7}$$

* * *

# Guided Wave Propagation in Submillimetric Region*

A. E. KARBOWIAK†

*Summary*—**An analysis of electromagnetic wave propagation in waveguides (in TH and TE modes) as well as in TEM transmission lines (*e.g.*, coaxial) at frequencies in the extremely high frequency band (30 to 300 kmc) and higher is carried out.**

**It is shown that in the case of metallic waveguides excited in $TE_0$ modes, the attenuation at sufficiently high frequencies is always proportional to $(\text{frequency})^{-3/2}$. On the other hand with TH waves (including TEM waves) although the attenuation at moderately high frequencies is proportional to $(\text{frequency})^{1/2}$, yet at sufficiently high frequencies the attenuation drops, becoming proportional to $(\text{frequency})^{-5/2}$. In other words, with TH waves the attenuation becomes a more rapidly decreasing funcion than it is with TE waves.**

**The analysis is concluded with numerical examples.**

## LIST OF SYMBOLS

$k_0 = 2\pi/\lambda_0 = \omega/c$ = free space propagation coefficient

$\lambda_0$ = free space wavelength

$h_0$ = cutoff coefficient of a perfect waveguide

$\gamma_0 = j\beta_0$ = propagation coefficient of a perfect waveguide

$h$ = cutoff coefficient of an imperfect waveguide

$\gamma = \alpha + j\beta$ = propagation coefficient of an imperfect waveguide

$\alpha$ = attenuation coefficient

$\beta = 2\pi/\lambda_g$ = phase propagation coefficient

$Z_s = |Z_s|/\phi_s = R_s + jX_s$ = surface impedance (normalized with respect to $Z_0$)

$Z = \sqrt{c\epsilon\mu_m/\mu_o\sigma}$ = a constant of a conductor

$\nu_{m,n}\nu'_{m,n}$ = characteristic numbers of wavemodes

$a, s, d$ = physical measurements of waveguides

The quantity $Z_0(=\sqrt{\mu_o/\epsilon})$ is absorbed in the symbol $H$ (magnetic field vector) and consequently all impedances are normalized with respect to that quantity.

## I. INTRODUCTION

THE purpose of this study is to investigate the behavior of waveguides as the frequency is raised indefinitely. The frequency band of interest ranges from the millimetric through the submillimetric and infrared region right up to the frequencies corresponding to the visible light.

In the analysis it is assumed that the waveguides concerned are (planar or cylindrical) of perfect geometry and that the physical properties of the waveguide walls are describable in terms of a single quantity $Z_s$, the surface impedance.[1]

In particular, if the walls are made of a good conductor it is stipulated that the conductor surface is perfectly smooth and that its impedance is proportional to the square root of the frequency [see (9)].

It is then shown that as the frequency is raised sufficiently above the cutoff value the attenuation of $TE_0$ waves falls off indefinitely since it becomes proportional to $(\text{frequency})^{-3/2}$.

With TH waves (including TEM), however, the attenuation is an increasing function of frequency—it is proportional to $(\text{frequency})^{1/2}$—but this is only true in a limited range of frequencies—and if the frequency is raised much above the cutoff value the whole mode pattern gradually changes into one having very low attenuation, in fact the attenuation under these conditions becomes proportional to $(\text{frequency})^{-5/2}$.

Throughout it is assumed that the surface impedance is a small quantity and therefore the above described effects are solely a result of operating the waveguide at frequencies very much above the cutoff frequency of the waveguide.

## II. PROPAGATION OF $TE_0$ WAVES IN PLANAR AND CIRCULAR WAVEGUIDES

Let all field quantities be proportional to

$$\exp(j\omega t - \gamma z) \tag{1}$$

where

$$\gamma = \alpha + j\beta = \text{propagation coefficient}$$
$$k_0^2 = h^2 - \gamma^2$$
$$h = \text{cutoff coefficient}$$
$$k_0 = \frac{\omega}{c} = \frac{2\pi}{\lambda_0} = \text{free-space propagation coefficient,} \tag{2}$$

then in the case of a parallel plate waveguide the value of the quantity $h$ is for any given $k_0$ and surface impedance, $Z_s$, determinable from[1,2]

$$\frac{Z_s}{k_0} = \frac{\tan ha}{h} \tag{3}$$

where $a$ is the distance between the parallel plates and $Z_s$ the surface impedance of one of the plates.

As explained elsewhere[1,2] by putting

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* Original manuscript received by the IRE, March 10, 1958, revised manuscript received, May 27, 1958.

† Standard Telecommun. Labs., Ltd., Enfield, Middlesex, Eng.

[1] A. E. Karbowiak, "Theory of imperfect waveguides: the effect of wall impedance," *Proc. IEE*, vol. 102B, p. 698; September, 1955.

[2] A. E. Karbowiak, "Waveguide characteristics" *Electronic and Radio Eng.*, p. 379; October, 1957.

$$h = h_0 + \delta h$$

$$h_0 = \frac{n\pi}{a} \ (n = \text{order of the mode}), \tag{4}$$

we can approximate to (4) and obtain

$$\delta h = \frac{1}{a}\,\frac{h_0}{k_0}\,(jZ_s) \tag{5}$$

provided

$$|Z_s| \ll 1 \tag{6}$$

where $Z_s$ and $\delta h$ are small quantities.

Substituting (5) back into (4) and (2) leads to an equation for $\gamma$ which for $k_0 \rightarrow \infty$ gives

$$\left.\begin{aligned} \beta &\simeq \beta_0 + \frac{1}{a}\,\frac{k_0}{\beta_0}\left(\frac{h_0}{k_0}\right)^2 X_s \simeq \beta_0 \simeq k_0 - \frac{1}{2}\,h_0^2/k_0 \simeq k_0 \\ \alpha &\simeq \frac{1}{a}\,\frac{k_0}{\beta_0}\left(\frac{h_0}{k_0}\right)^2 R_s \simeq \frac{1}{a}\left(\frac{h_0}{k_0}\right)^2 R_s \end{aligned}\right\} \tag{7}$$

where

$$Z_s = R_s + jX_s. \tag{8}$$

Eq. (7) shows various degrees of approximation which are valid for larger and larger values of $k_0$ ($\propto$ frequency).

Thus provided that $|Z_s| \ll 1$, then for arbitrarily large values of frequency, (5) is a valid representation of (4) and therefore (7) is true, however large $k_0$ may be.

Thus, for example, if the waveguide walls are made of a plain metallic conductor of perfect geometry, then

$$\begin{aligned} Z_s &= \sqrt{\frac{\omega\mu_m}{\sigma}}\sqrt{\frac{\epsilon_0}{\mu_0}} \Big/ \frac{\pi}{4} \\ &= k_0^{1/2} Z \Big/ \frac{\pi}{4} \end{aligned} \tag{9}$$

where

$$Z = \sqrt{c\epsilon_0\mu_m/\mu_0\sigma} \tag{10}$$

and we get

$$\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{Z}{a}\,\frac{h_0^2}{\sqrt{2}k_0^{3/2}} = \frac{(n\pi)^2}{\sqrt{2}}\,\frac{Z}{a^3}\,k_0^{-3/2} (k_0 \rightarrow \infty). \end{aligned} \tag{11}$$

For a circular waveguide we get similar results, namely,

$$\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{Z}{S}\,\frac{h_0^2}{\sqrt{2}k_0^{3/2}} = \frac{(\nu_{0n}')^2}{\sqrt{2}}\,\frac{Z}{S^3}\,k_0^{-3/2} \end{aligned} \tag{12}$$

where $S$ is the radius of the waveguide and $\nu_{0n}'$ is the $n$th root of $J_0'(x) = 0$.

Fig. 1 shows the $\alpha$ and $\beta$ curves in particular illustrating the $k_1^{-3/2}$ law at the high-frequency end.

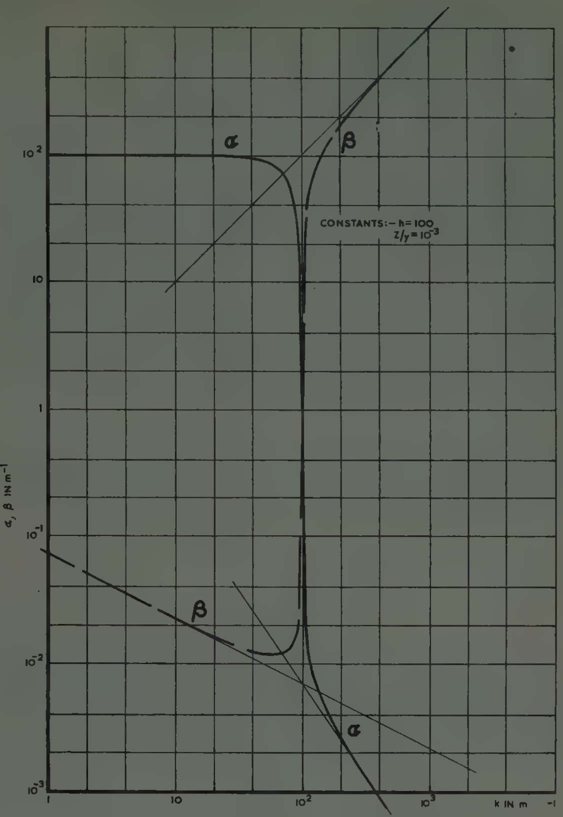

Fig. 1—$\alpha$ and $\beta$ coefficients of a circular waveguide carrying a $TH_0$ mode.

## III. PROPAGATION OF TH WAVES IN PLANAR AND CIRCULAR WAVEGUIDES

With TH waves, for planar waveguides, instead of (3), the following equation has to be solved:[1,2]

$$jZ_sk_0 = h \tan ha. \tag{13}$$

The notation being the same as with TE waves.

Again using the substitution (4), an approximate solution to (13) may be obtained[1]

$$\delta h = \frac{1}{a}\,\frac{k_0}{h_0}\,(jZ_s). \tag{14}$$

Substituting this equation back into (4) and (2) leads to an equation for the propagation coefficient, $\gamma$, which for large values of $k_0$ gives

$$\left.\begin{aligned} \beta &\simeq \beta_0 + \frac{1}{a}\,\frac{k_0}{\beta_0} X_s \simeq \beta_0 \simeq k_0 - \frac{1}{2}\,\frac{h_0^2}{k_0} \simeq k_0 \\ \alpha &\simeq \frac{1}{a}\,\frac{k_0}{\beta_0} R_s \simeq \frac{1}{a} R_s \end{aligned}\right\}. \tag{15}$$

Within the validity of the approximations involved we get in the simple case of a plain metallic waveguide [substitutions (9) and (10)], that

$$\left.\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{1}{\sqrt{2}}\,\frac{Z}{a}\,k_0^{1/2} \ (k_0 \text{ large}) \end{aligned}\right\}. \tag{16}$$

For a circular waveguide we would have

$$\left.\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{1}{\sqrt{2}}\,\frac{Z}{S}\,k_0^{1/2} \end{aligned}\right\}. \tag{17}$$

These equations illustrate the familiar law $\alpha \propto k_0^{1/2}$.

In the above derivation of the relevant formulas it was, of course, assumed that $|Z_s| \ll 1$. This evidently is a necessary condition, fulfilled in the majority of practical cases, yet, it will be observed that the limit $k_0 \to \infty$ cannot be approached; since however small $Z_s$ may be, for $k_0 > (1/|Z_s|)$, (14) no longer represents a small quantity and therefore ceases to be a valid approximation to (13).

To investigate the behavior of $\alpha$ and $\beta$ quantities for $k_0 \to \infty$ we put

$$\left.\begin{aligned} h &= h_0' + \delta h' \\ \text{where}\qquad & \\ \cot\,(ah_0') &= 0 \end{aligned}\right\}. \tag{18}$$

With this substitution in (13) we expand cot $(ah)$ in its Taylor's series about the point $ah_0'$ and retaining only the first term of the expansion we get

$$\delta h' = j\,\frac{h_0'}{k_0}\,\frac{1}{aZ_s}\,. \tag{19}$$

Substituting (19) and (18) into (2) yields eventually

$$\begin{aligned} \gamma &= \sqrt{h^2 - k_0^2} \\ &\simeq jk_0\left[1 - \frac{1}{2}\left(\frac{h_0'}{k_0}\right)^2\right] + \left(\frac{h_0'}{k_0}\right)^2 \frac{1}{aZ_s}\,. \end{aligned} \tag{20}$$

Consequently

$$\left.\begin{aligned} \beta &\simeq k_0 - \frac{1}{2}\left(\frac{h_0'}{k_0}\right)^2 - \frac{1}{a}\left(\frac{h_0'}{k_0}\right)^2 \frac{X_s}{|Z_s|^2} \\ \alpha &\simeq \frac{1}{a}\left(\frac{h_0'}{k_0}\right)^2 \frac{R_s}{|Z_s|^2} \end{aligned}\right\} \tag{21}$$

As an illustration consider a plain metallic waveguide. Here the substitution of (9) and (10) into (21) yields for $k_0 \to \infty$

$$\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{(h_0')^2}{a\sqrt{2}}\,Z^{-1}k^{-5/2} = \frac{(n-\frac{1}{2})^2\pi^2}{\sqrt{2}}\,\frac{Z^{-1}}{a^3}\,k^{-5/2}. \end{aligned} \tag{22}$$

For circular waveguides we would have

$$\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{(h_0')^2}{S\sqrt{2}}\,Z^{-1}k^{-5/2} = \frac{(\nu'_{m(n-1)})^2}{\sqrt{2}}\,\frac{Z^{-1}}{S^3}\,k^{-5/2} \end{aligned} \tag{23}$$

where $\nu_{mn}'$ is the root of $J_{m(n-1)}'(x) = 0$ and $S$ is the radius of the waveguide.

These equations show that at extremely high values of frequency the attenuation of waveguides, when supporting TH modes, falls off indefinitely; in fact the attenuation is proportional to $S^{-3}k_0^{-5/2}$ rather than (as implied by conventional formulas) proportional to $S^{-1}k^{1/2}$.

To investigate this, somewhat unusual, behavior of TH waves (13) has been solved numerically for the entire frequency range from $-\infty$ to $+\infty$ for a hypothetical planar waveguide and hence $\alpha$ and $\beta$ curves computed (Fig. 2). In the case of circular waveguides the $\alpha$ and $\beta$ curves would be similar and any differences would be only in detail, rather than in the general shape of the curves.

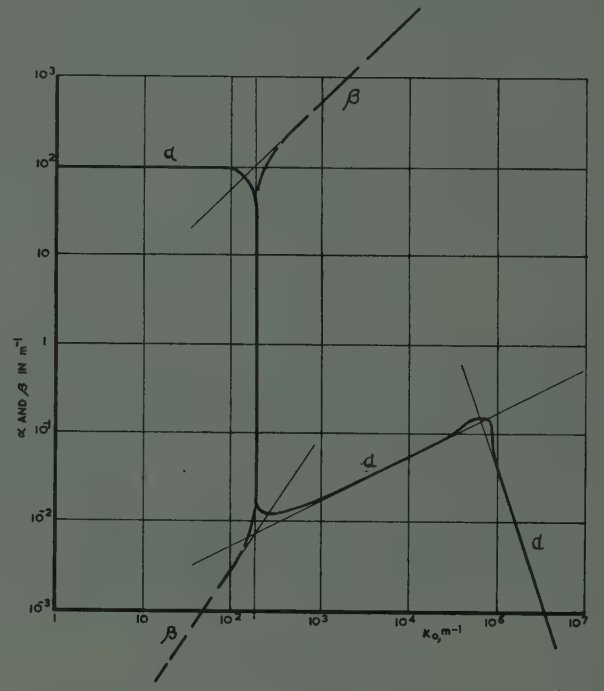

Fig. 2—$\alpha$ and $\beta$ curves for a planar waveguide excited in the $TH_0$ mode. Constants of the guide, $a$ = separation between planes = 1.3 cm, $z/a$ $10^{-5}$ $m^{1/2}$.

## IV. PROPAGATION OF TEM WAVES

As an example of TEM wave propagation let us consider the propagation of a plane TEM wave in parallel plate waveguide.

If $z$ is the direction of propagation and the plate at $x=0$ is perfectly conducting, while the plate at $x=a$ exhibits a surface impedance $Z_s$ then the following equations for the field components are valid

$$\left.\begin{aligned} E_z &= h \sin hx \\ H_y &= -jk_0 \cos hx \\ E_x &= -\gamma \cos hx \end{aligned}\right\} \tag{24}$$

where $k_0$, $\gamma$, and $h$ are connected by (2) and, of course, for a TEM wave $h$ would be zero, but in the case considered (an imperfect waveguide) a pure TEM wave is not possible and $h$ is finite (though usually a very small quantity), determinable from the boundary condition at $x=a$, namely,

$$Z_s = -\frac{E_z}{H_y}\bigg|_{x=a} = \frac{h \sin ha}{jk_0 \cos ha}, \tag{25}$$

i.e.,

$$jk_0 Z_s = h \tan ha. \tag{26}$$

We note that the characteristic equation (26) is the same as with TH waves [as (13)] and therefore the shape of $\alpha$ and $\beta$ curves in the upper frequency range will be similar to that for TH waves.

In particular, it can be shown that for large values of $k_0$ the $\alpha$ and $\beta$ coefficients are given by (15) while for $k_0 \to \infty$ we have from (22) (by setting $n=0$)

$$\left.\begin{aligned} \beta &\simeq k_0 \\ \alpha &= \frac{(\pi/2)^2}{\sqrt{2}} \frac{Z^{-1}}{a^3} k_0^{-5/2} \end{aligned}\right\}. \tag{27}$$

Eq. (26) has been solved for the entire frequency range for a parallel plate waveguide with $a=d=10^{-2}$ m and conductivity $(\sigma)=5.8\times10^7$ mhos/m. The values of $h$ so computed were subsequently substituted in (2) and $\alpha$ and $\beta$ coefficients evaluated and plotted in Fig. 3.

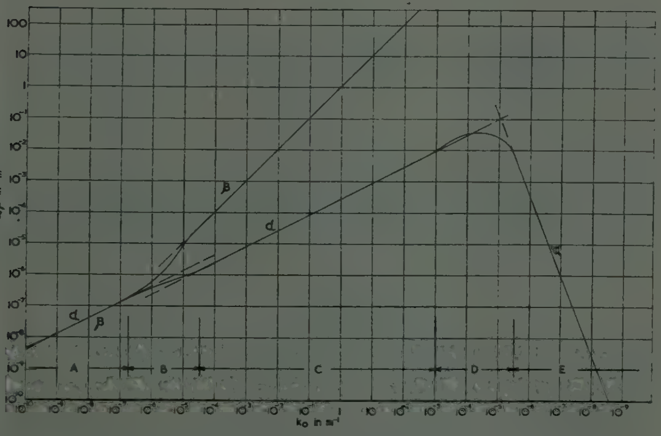

Fig. 3—$\alpha$ and $\beta$ as functions of $K_0$ for a TEM wave where $a=10^{-2}$ m and $\sigma=5.8\times10^{-7}$ mhos/m, $d=10^{-2}$ m.

It will be observed that the whole frequency range can be divided into six fairly distinct intervals:

1) Very low frequency range ($A$) ($f<100$ cps approximately) where $\alpha$ and $\beta$ are given approximately by

$$\left.\begin{aligned} \alpha &\simeq \operatorname{Re}\left\{j\frac{Z_s k_0}{a}\right\}^{1/2} \\ \beta &\simeq I_m\left\{j\frac{Z_s k_0}{a}\right\}^{1/2} \end{aligned}\right. \tag{28}$$

which for a plain metallic waveguide gives

$$\alpha \simeq \beta \simeq Z(ad)^{-1/2} k_0^{1/2} \tag{29}$$

where $a$ is the separation between the plates, $d$ their thickness and $Z$ is a constant of the metal concerned ($=6.8\times10^{-6}$ for copper).

2) Low-frequency transition region $B$ (100 cps $<f<10$ kc, approximately) where $\beta$ changes its functional dependence, as the frequency increases, from $\beta \propto k_0^{1/2}$ to $\beta \propto k_0$.

3) Medium to very-high-frequency region $C$ (10 kc $<f<100$ kmc

$$\left.\begin{aligned} \beta &\simeq k_0 + \frac{1}{2}\frac{X_s}{a} \simeq k_0 \\ \alpha &\simeq \frac{1}{2}\frac{R_s}{a} \end{aligned}\right\}. \tag{30}$$

which for a plain metallic waveguide becomes

$$\left.\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \frac{1}{2}\frac{Z}{\sqrt{2}} a^{-1} k^{1/2} \end{aligned}\right\}. \tag{31}$$

4) A high-frequency transition region $D$ ($10^{11}<f<10^{13}$ cps) where $\beta$ retains its functional dependence $\beta \propto k_0$ but $\alpha$ changes its functional dependence from $\alpha \propto k_0^{5/2}$ to $\alpha \propto k_0^{-5/2}$.

5) Submillimetric region $E(10^{13}<f<10^{16})$ where

$$\begin{aligned} \beta &\simeq k_0 \\ \alpha &\simeq \left(\frac{\pi}{2}\right)^2 a^{-3} k^{-2} R_s |Z_s|^{-2} \end{aligned} \tag{32}$$

which for plain metallic waveguides leads to

$$\alpha \simeq \frac{(\pi/2)^2}{\sqrt{2}} a^{-3} Z^{-1} k_0^{-5/2}. \tag{33}$$

6) Region $F$ of violet and ultraviolet light where even for plain metallic waveguides $Z_s$ is no longer a small quantity, it is no longer given by (9) and (10) and consequently the results of the analysis are not applicable.

## V. Some Numerical Examples

Let $\alpha_H$ be the attenuation of $TE_0$ waves, for $k \to \infty$ and $\alpha_E$ stand for the same quantity for TH waves. On equating the $\alpha_E$ and $\alpha_H$ quantities [(11) and (22) for planar, (12) and (23) for circular waveguides] we find that this particular value of $k_0$ is given by

$$k_c = \left(1 - \frac{1}{2n}\right)^2 Z^{-2} \text{ (for planar waveguides)} \tag{34}$$

$$k_c = \left[\frac{\nu'_{0(n-1)}}{\nu_{0n}'}\right]^2 Z^{-2} \text{ (for circular waveguides)}. \tag{35}$$

Below the value $k_c$ we have $\alpha_H < \alpha_E$ and above, $\alpha_E < \alpha_H$.

For planar copper waveguide ($Z=6.8\times10^{-6}$) operated in the lowest mode ($n=1$) the quantity $k_c$ is

$5.4\times10^9$ m$^{-1}$ which corresponds to a frequency $2.6\times10^{17}$ cps. This frequency is even above the frequency of visible light and consequently we can say that out of all the modes in a hollow circular metal waveguide the TE$_{01}$ mode seems to have the lowest attenuation, though at frequencies above the usable range other modes, notably the TH modes, can have even lower attenuation.

As a numerical example consider a planar waveguide ($Z=10^{-5}$) excited in the lowest TH mode at a frequency corresponding to the yellow spectrum of visible light ($\lambda_0=5.5\times10^{-7}$ m) where the separation between the guiding planes is $a=10^{-4}$ m.

The conventional formula (16) gives for this case

$$\alpha_c \simeq \frac{1}{\sqrt{2}}\,\frac{Z}{a}\,k_0^{1/2} = 2080 \text{ db/m} \qquad (36)$$

whereas the corrected (33) gives

$$\alpha_E = \frac{(\pi/2)^2}{\sqrt{2}}\,a^{-3}Z^{-1}k_0^{-5/2} = 3.43 \text{ db/m} \qquad (37)$$

the difference between the two results is, evidently, enormous.

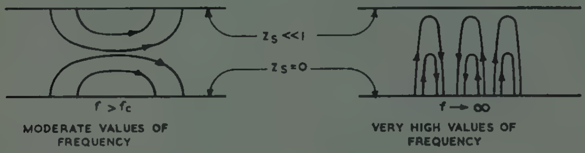

Fig. 4—Electric lines of force of a TH$_{01}$ mode in a waveguide with one imperfect wall.

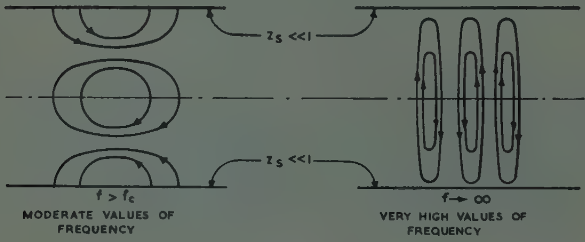

Fig. 5—TH$_{02}$ mode in an imperfect waveguide.

## VI. Mode Notation and Description

In Sections III and IV we have established the somewhat unusual behavior of TH waves, when the waveguides are operated at extremely high frequencies, in that as the frequency is increased then not only does the attenuation change from $\alpha \propto f^{1/2}$ to $\alpha \propto f^{-5/2}$ but also that the cutoff coefficient changes from $h_0$ to $h_0'$ and consequently the field configuration is thereby altered.

Figs. 4 and 5 illustrate this change in the field configuration of TH modes.

We now propose to extend the conventional mode notation $M_{m,n,l}$ to include the cases in Figs. 4 and 5, as follows.

In the case of a perfect waveguide the symbol $M_{m,n,l}$ stands for an TH mode if M = TH and an TE mode if M = TE. The suffixes have the following significance:

$m(=0, 1, 2, \cdots)$ = circumferential (coordinate $u$)
$n(=\bullet, \times, 0, 1, 2, \cdots)$ = radial (coordinate $v$)
$l(=\bullet, \times, 0, 1, 2, \cdots)$ = axial (coordinate $z$)

where ● signifies that the mode is propagating in that particular direction, × signifies that the mode is evanescent in that particular direction, and the integers indicate the number of field nodes in that particular dimension.

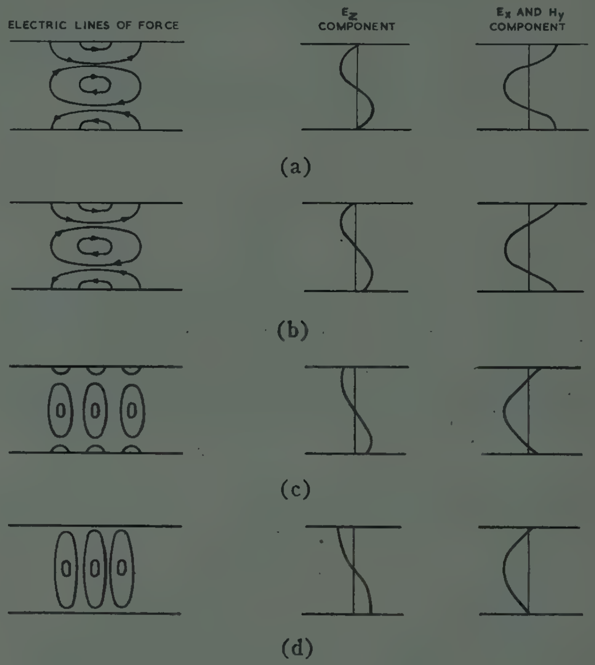

Fig. 6—Field quantities of a TH$_{02}$ mode for various frequencies. (a) for $Z_s=0$ and $f>f_c$, (b) for $Z_s\ll1$ and moderate values of frequency, (c) for $Z_s\ll1$ and large values of frequency, (d) for $Z_s\ll1$ and $f\to\infty$.

Let us now consider the field lines of a TH$_{02\bullet}$ mode. In the case of a perfect waveguide the field lines are as shown in Fig. 6(a).

If the waveguide is imperfect ($Z_s\neq0$), however, then the field lines will be slightly altered as indicated in Fig. 6(b). But if now the frequency is raised indefinitely then the field pattern will gradually change to the field configuration as indicated in Fig. 6(c) and eventually as shown in Fig. 6(d). Evidently the number of field nodes has changed from 2 to 1. To be more precise the radial suffix, $n$, has changed from the value 2 through all the fractional values to the value 1 but the resultant field pattern [Fig. 6(d)] is not that of a TH$_{01}$ mode. Whereas the TH$_{01}$ mode is a highly attenuating mode ($\alpha\propto f^{1/2}$), the mode in Fig. 6(d) has in general a very low attenuation ($\alpha\propto f^{-5/2}$); in fact it is the lowest possible mode in an imperfect waveguide, that can be supported if the frequency is sufficiently high. We propose to call this mode a TH$_{01}^{\infty}$. In general, as the frequency increases a TH$_{0n}$ mode passes into a TH$^{\infty}_{0(n-1)}$ mode with the addition that a TEM mode passes into an TH$_{01}^{\infty}$ mode.

## VII. Conclusions

It has been shown that as the frequency of the operation of waveguides is raised sufficiently above the cutoff value, then the attenuation of the $TE_{0n}$ waves is proportional to $f^{-3/2}$ whereas with TH waves, it is proportional to $f^{1/2}$. Consequently the attenuation of $TE_{0n}$ waves decreases indefinitely whereas that of TH waves increases. As the frequency, however, is increased further and further the attenuation of the $TE_{0n}$ waves continues to decrease but the attenuation of TH waves begins to drop and eventually it becomes proportional to $f^{-5/2}$. That is, the rate of decrease of the attenuation of TH waves becomes higher than that of TE waves; yet right up to the visible spectrum the attenuation of TE waves is significantly lower than that of TH waves.

## VIII. Acknowledgment

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# Solar Cycle Influence on the Lower Ionosphere and on VHF Forward Scatter*

C. ELLYETT† AND H. LEIGHTON‡

*Summary*—**A brief survey of published literature indicates that the electron concentration in the *D* region of the ionosphere changes with the solar cycle. Such changes should also be apparent in VHF forward scatter signal intensities.**

**Analyses have therefore been made of seven years' results, at 49.8 mc from the Cedar Rapids, Iowa, to Sterling, Va., forward scatter path (1243 km). On an annual basis, it is found that the monthly median received signal intensity, for the noon and afternoon period only, follows the same trend as the mean monthly sunspot number. The effect is still more pronounced when comparison is made with magnetic disturbance indexes.**

**However, when the comparison with magnetic indexes is made using a direct comparison in each 3-hour period, and eliminating long-term trends, no observable increase of the signal intensity is found as the magnetic conditions become disturbed. This is in sharp contrast to the behavior of such circuits in auroral regions. Further analysis shows that a weak increase in signal intensity with a rising magnetic index does occur if the analysis is confined to the midday period.**

**It is concluded, therefore, that any magnetic influence is smaller on middle than on high latitude scatter circuits, but an effect can be clearly discerned by studying the magnitude of the received signal through a solar cycle. These results show that VHF forward scatter signals are not caused by reflection from meteor trails alone.**

## I. Introduction

IT IS NOW well known that the lower ionosphere, below the *E* region, can partially reflect or scatter both vertical and oblique radio signals. Many of the direct experiments at medium frequencies have shown the existence of low layer ionospheric stratification.[1–5] Reflection coefficients of the various layers, and the height variation of the layers with time, have been obtained.

Also many reports have been made of determinations of the height of reflection of oblique transmissions at various frequencies ranging from VLF right through to VHF.[6–8] Although variations occur, the predominant night-time height, for signals transmitted by a lower ionospheric mechanism, is about 85–90 km, with a fall during daylight hours to approximately 70 km evident from VLF oblique and MF vertical experiments.

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The close similarity of heights obtained on both vertical and oblique transmissions led Bailey, Bateman, and Kirby[8] to suggest that the same region was operative in both cases. Wheelon[9] has reviewed the evidence for such a correspondence in some detail, and strongly concludes that the regions are identical. Still more recently, Gregory[10] has shown that an almost perfect correspondence exists between VHF forward scatter height and time variations, as obtained by Pineo[11] in America, and vertical echoes at 1.75 mc, measured in New Zealand. It can therefore be concluded with some certainty that the regions causing both vertical MF reflections and oblique VHF scattering are identical.

If this premise is accepted, then variations in the occurrence and strength of the ionospheric $D$ region during a solar cycle should be matched by variations in oblique VHF signal intensities. The first purpose of the present paper is to review any evidence for a solar cycle effect in the $D$ region ionization.

Nearly seven years of continuous signal intensity results are now available on the Cedar Rapids, Iowa, to Sterling, Va., VHF forward scatter circuit, operated at 49.8 mc by the National Bureau of Standards.[12] Results over this period of time, covering, as they do, both a minimum and a maximum of the sunspot cycle, might be expected to show some solar influence, unless the causative agent of the layers is entirely meteoric. It has already been established in America,[13–15] Canada,[16] and England,[17] as a result of off-great-circle path studies of forward scatter, that meteors play a large part in scatter communication. Solar influences do seem necessary, however, to explain the simultaneous broad maxima observed on various paths through the midday and early afternoon period.[15] It seems worthwhile, therefore, to search the Cedar Rapids to Sterling results for a possible solar cycle influence.

Correspondence between long-term variations of the solar cycle and the magnetic $K$ index has long been known. If a solar influence is established for scatter circuits, they might also be expected to be sensitive to long-term magnetic variations.

Again, it has been known for several years, as a result of the work of Bailey, Bateman, and Kirby[8] on Arctic region circuits, that increasing $K$ index, indicating increasing magnetic disturbance, causes an *improvement* in the scattered signal intensity. (This behavior is contrary to that of other communication systems which use conventional refraction from the upper ionospheric layers. Reliability in periods of magnetic disturbance is one of the major advantages of scatter propagation in the Arctic.) It is therefore of considerable interest to see whether lower latitude scatter circuits are influenced in a similar manner by magnetic behavior. This study concludes the paper.

## II. SOLAR CYCLE INFLUENCE ON D-REGION IONIZATION

The $D$ region of the ionosphere has long been recognized as the principal region of absorption of electromagnetic waves. This has required the presence of at least a weak free-electron concentration.

For many years, in addition to the absorption evidence discrete echoes at heights below the normal $E$ region have been reported, but these reports have been most conflicting.[18] It is only in the last five years, largely through improved techniques, that unequivocal evidence has been obtained of partial reflection from stratified regions in the virtual height range lying between 50 and 100 km.[1–5] Such echoes, particularly for the main 85-km layer, but sometimes also for the 70-km region, persist throughout the day and night.[19] No evidence of a $D$-region solar cycle effect is therefore likely to be obtained from other than absorption data, solar radiation data, and experiments specifically carried out in the past five years to measure the low-layer stratification.

### *Absorption Data*

It has been known for at least a decade that absorption follows the sunspot cycle. The absorption of HF radio waves passing through the $D$ region increases by a factor of approximately 1.5 between sunspot number zero and 100.[20] This work is supported by more recent absorption work at Dakar, French West Africa,[21] from which it is again concluded that the $D$-layer electron density increases proportionally to the sunspot cycle.

(Absorption at VHF is very much reduced, compared to HF, and any 11-year cycle effect in absorption would almost certainly be masked by other variations.[20])

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[12] Since the work was done on this paper, new measurements have been made of antenna gains at the Cedar Rapids and Sterling stations. The gain at each station was found to have deteriorated relative to that measured earlier in the course of the experiment. It may be expected that this change has caused the rise in signal strengths, shown in figures in this paper during years of rising sunspot cycle, to be somewhat less than actually occurred.

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### *Solar Radiation Data*

Direct rocket data on the very low electron concentrations likely to be encountered in the *D* region do not yet appear to have been obtained, but there are now available many rocket measurements of the incident solar flux of both hydrogen Lyman-$\alpha$ radiation, and X rays below 20 A. Both these radiations penetrate into the *D* region, creating ionization at least down to 75 km.

Values of the solar X-ray flux have been reported from one flight in 1949, three in 1952, three in 1953, and one each in 1955 and 1956. When the summary table[22] is compared with the sunspot curve a reasonable correspondence by years is apparent.

The evidence for a solar cycle variation of Lyman-$\alpha$ radiation is still quite weak. Some twelve intensity measurements are available,[22,23] comprising one in 1949, one in 1950, three in 1952, one in 1954, four in 1955, and two in 1956. The distribution of flights during the solar cycle is good, and a flux decline, agreeing with the cycle, is evident from 1949 through 1952. Values in 1955 and 1956 have increased with the solar cycle rise, but a change in instrumentation introduces some uncertainty into the values. This section can be summarized by stating that direct measurements of the radiations likely to be responsible for *D*-region ionization are in reasonable agreement with the hypothesis of a solar cycle influence, without being conclusive.

### *Radio Data*

Here evidence is meager indeed. The few papers available on vertical incidence observations are as yet largely qualitative, although two recent papers give values for reflection coefficients.[3-5] Continued observation over a period of several years, with controlled parameters, should now be straightforward, and should give a direct answer to this problem.

Considering the three subsections together, there is quite strong evidence of a definite parallel movement of the electron concentration of the lowest regions of the ionosphere and the 11-year cycle of sunspot numbers.

## III. Solar Cycle Influence on VHF Forward Scatter

If solar cycle behavior exerts an influence on the 85-km region, it should also influence oblique VHF signal intensities, since such signals are observed to be scattered from this height.

Median signal intensity values on an hourly basis are available from the Cedar Rapids to Sterling oblique path from January 1, 1951 to November 30, 1957. Some three and one half years of falling sunspot cycle are thus covered, including the minimum in April, 1954, followed by a steep rise to, or very near, the maximum at the end of 1957. The records of received intensity, following previous practice,[8] have been grouped into four separate median values for each month for the 3-hour periods centered about 00, 06, 12, and 18 hours local time at the path midpoint.

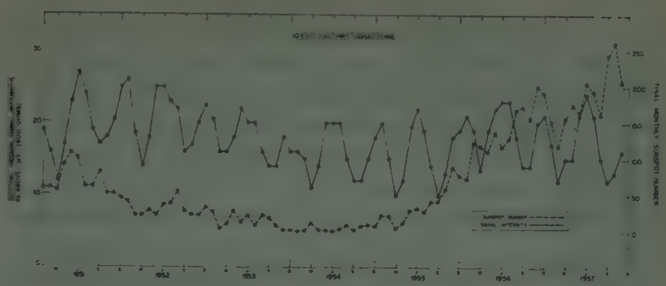

Fig. 1—Cedar Rapids to Sterling forward scatter at 49.8 mc.

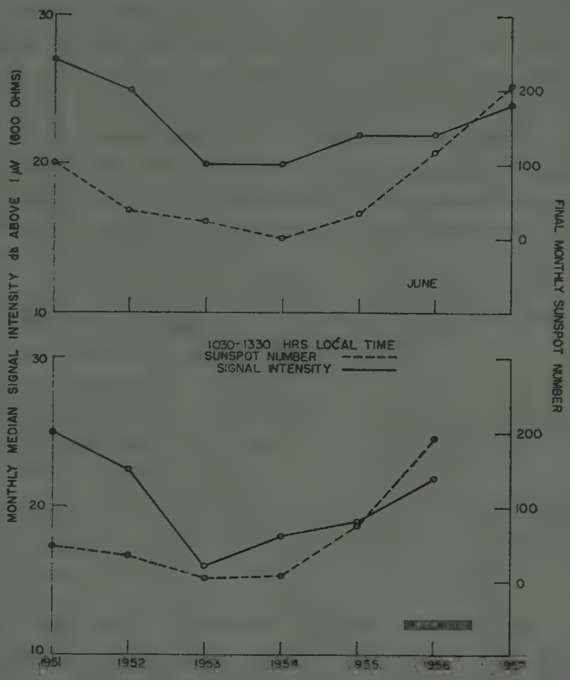

Fig. 2—Cedar Rapids to Sterling forward scatter at 49.8 mc.

The strongest solar control during the day would be expected in the 3-hour period around noon. The graph of monthly median signal intensity covering this period is given in Fig. 1, together with the curve of final monthly sunspot numbers. Some general correspondence is apparent, but the forward scatter values are strongly influenced by a semiannual period. To overcome the effect of this period, comparison of the two curves in Fig. 1 has been made for the same month in each year. At the months of peak signal intensity, as shown for June and December in Fig. 2, an excellent trend comparison is evident. Other months are not so clearcut.

Twelve indexes were next obtained from Fig. 1—one for each month of the year—by simply noting whether the trend between the two curves was in parallel or opposition as the same month was followed from year to year. Some cases occurred where the median signal intensity was the same value on the same month in adjacent years. These cases were excluded from the total. Proceeding in this manner for each month, and totalling the indexes, when all the months were combined it was found that the trend was in opposition in 21 cases, and in parallel in 46. It has already been noticed on this circuit that the diurnal peak of the signal intensity is displaced to the afternoon side of noon.[8] Consequently, it could be predicted that if the present method of analysis is significant, the departure of the curves from random movement should be greatest in the noon period, present in the period centered on 18 hours very weak in the 06 hour period, and lost—possibly by obscuring meteor activity—in the 00 hour period. The results of the analysis are given in Table I, where it is evident that the exact behavior predicted is occurring.

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[22] T. A. Chubb, H. Friedman, R. A. Kreplin, and J. E. Kupperian, "Lyman Alpha and X-ray emissions during a small solar flare," *J. Geophys. Res.*, vol. 62, pp. 389–398; September, 1957.

[23] E. T. Byram, T. A. Chubb, H. Friedman, and J. E. Kupperian, "Observations of the intensity of solar Lyman-Alpha emission," *Astrophys. J.*, vol. 124, pp. 480–482; September, 1956.

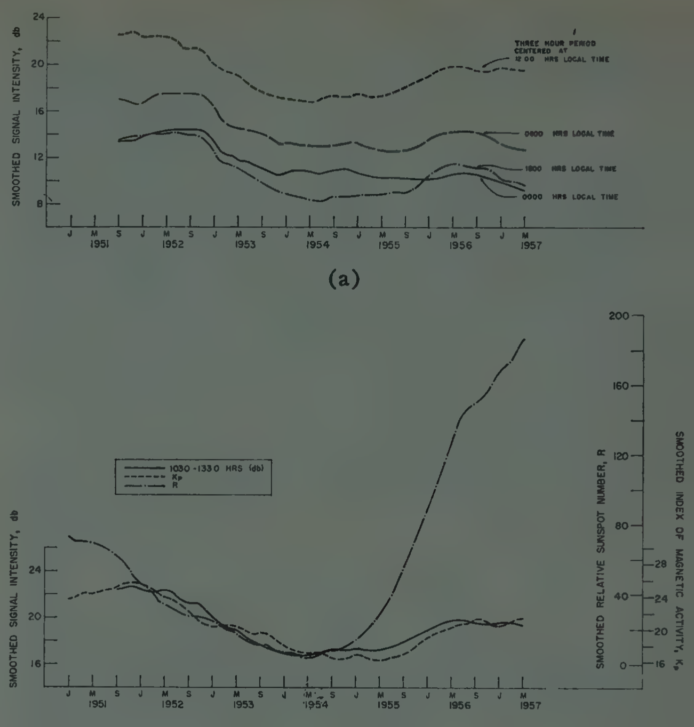
TABLE I

Comparison of Trend Between Forward Scatter Signal Intensity and Sunspot Number

| Three-hour period centered about | Similar-month movement of values 1951–1957 | | Percentage of total cases favoring parallel movement (random = 50 per cent) |
|---|---|---|---|
| | In opposition | In parallel | |
| 06 hours | 25 | 27 | 52 |
| 12 hours | 21 | 46 | 69 |
| 18 hours | 22 | 39 | 64 |
| 00 hours | 32 | 23 | 42 |

Twelve-month running averages of the signal intensity for each of the four daily periods examined are given in Fig. 3(a). Some similarity is evident among the curves. The noon curve is always the strongest, and is the only one of the four which has not shown a fall from May, 1956 to May, 1957 when the sunspot curve has been rising sharply. Various tentative explanations could be suggested to account for the rough similarity of the four curves. Probably all that is worth saying at present is that a change in the incoming meteoric flux provides about the *least* likely explanation of the causative agent for a trend over the years which exhibits some similarity at all hours of the day.

The noon signal intensity curve has been redrawn in Fig. 3(b), together with the 12-month running means of the final monthly sunspot numbers, and the monthly magnetic indexes. It appears at once that the signal intensity follows the magnetic index much more closely than the sunspot curve. The well-known lag of the magnetic figures on the sunspot numbers is evident,[24] and the signal intensity parallels the magnetic figures. These curves could indicate that smoothed sunspot numbers are not necessarily a particularly good measure of the sun's long-term effect on the lower ionosphere, at least when the sun is in a very active condition.



(a)

(b)

Fig. 3—Comparison of sunspot number and magnetic activity with Cedar Rapids to Sterling signal intensities.

This section can be summarized by saying that some solar control of the daytime forward scatter signal on a temperate latitude path is undoubtedly present, as evidenced by intercomparison with the solar cycle.

## IV. Short Period Magnetic Influence on VHF Forward Scatter

The method of obtaining a comparison between magnetic indexes and signal intensities was somewhat involved. The procedure was as follows:

1) A single value of the median received signal intensity level was obtained by inspection for each hour of every day from the continuous pen recording.

2) A single median value was next obtained for each 3-hour period in the day, agreeing in time with the 3-hour intervals on which world magnetic activity figures are based.

3) Eight monthly median signal intensity values were obtained for the eight 3-hour intervals of the day.

4) The departure of each separate 3-hour unit signal intensity value from the monthly median covering the same time was recorded next.

5) The values of these departures were then collected, for thirteen consecutive months of observation, for all cases where the accompanying planetary magnetic *K* index had zero value (quietest magnetic conditions). The median of these values then expresses the integrated departure of the signal intensity from the median monthly values over the whole period.

The grouping was repeated for each magnetic index up to 6, with a final group for index 7 and above (most disturbed conditions).

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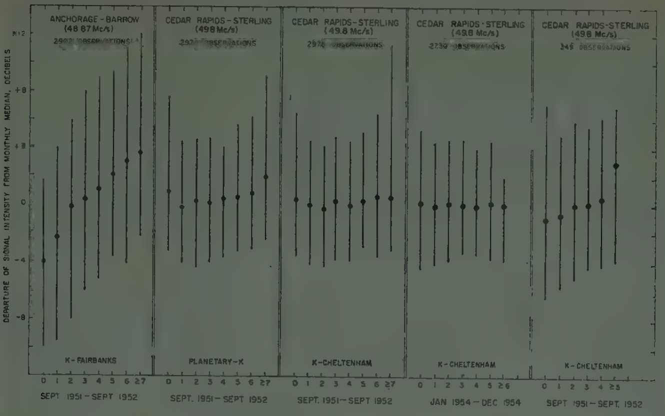
[24] S. Chapman and J. Bartels, "Geomagnetism," Oxford University Press, Oxford, Eng., p. 371; 1940.



(a) (b) (c) (d) (e)

Fig. 4—Comparison of signal intensity observations with magnetic *K* indexes.

This process was originally carried out for the Anchorage to Barrow, Alaska, circuit, where the midpoint was in the zone of maximum auroral occurrence.[8] The correlation then obtained, with the *K* indexes observed at Fairbanks, Alaska, is reproduced in Fig. 4(a). This result was used by Bailey, *et al.*,[8] to establish the very significant fact that VHF Arctic communications via scatter improve during periods of auroral and magnetic disturbance. (The limits of the vertical lines in the figure give the upper and lower decile values.)

Results for the temperate latitude Cedar Rapids to Sterling circuit, with an identical observing period, and planetary *K* indexes, are shown in Fig. 4(b). There is no correlation. This unexpected result was checked by repeating the analysis with the Cheltenham, Md., local *K* indexes—these being the nearest magnetic observations to the Cedar Rapids circuit. Again, as shown in Fig. 4(c), correlation is nonexistent. As a final check, the analysis was repeated for the 1954 signal intensity values against the Cheltenham *K* indexes [Fig. 4(d)], with an even more certain absence of any effect.

The method adopted in the above analysis is particularly designed to eliminate any possible long-period trends, such as seasonal or 11-year cycle effects, in the signal intensity records. The comparison of each 3-hourly signal intensity value is made with the magnetic index recorded *for the same period*, and all parts of the day and night are given equal weight. It can therefore be concluded from this section of the analysis that in temperate latitudes, in contrast to the auroral zone, there is no appreciable instantaneous relation between the forward scatter signal intensity and the magnetic disturbance figure.

It is possible, however, that the scatter component of meteoric origin is a relatively larger part of the total signal in temperate latitudes during the night and morning, so that it swamps any small magnetic effect being looked for on a 24-hour basis. Consequently, the comparison analysis was again repeated with a restriction to the period 10–13 hours local time. This period was the nearest to noonday which could be selected to fit the unit period of the magnetic indexes. It has already been established from the sunspot cycle study in Section III that the scatter circuit is *most* affected by solar influence around midday. Magnetic indexes are related to sunspot values, so if a "same-time" comparison is to show any relationship between the two phenomena, the probability is greatest around the noon period. The result is given in Fig. 4(e), where a small trend is indeed now apparent. High magnetic indexes, if they occur in the noon period, are thus accompanied by a slight increase in signal intensity.

## V. LONG PERIOD MAGNETIC INFLUENCE ON VHF FORWARD SCATTER

By using mean monthly values of the planetary *K* index, and comparing the trends between identical months in consecutive years with the trends in monthly median signal intensity, in exactly the same way as was done with the monthly sunspot numbers in Section III, it becomes possible to identify long-period effects. Table II has been prepared in this way.

TABLE II

COMPARISON OF TREND BETWEEN FORWARD SCATTER SIGNAL INTENSITY AND PLANETARY MAGNETIC INDEX

| Three-hour period centered about | Similar-month movement of values 1951–1957 | | Percentage of total cases favoring parallel movement (random = 50 per cent) |
|---|---|---|---|
| | In opposition | In parallel | |
| 06 hours | 17 | 35 | 67 |
| 12 hours | 14 | 47 | 77 |
| 18 hours | 17 | 44 | 72 |
| 00 hours | 25 | 30 | 55 |

The similarity of trends is more marked than in Table I. The signal intensity over the years definitely parallels the magnetic index in the afternoon period, and, in comparison with the sunspot results, now appears to show some parallelism even in the fairly early morning. Once again the midnight value shows no significant correlation.

The conclusion from these magnetic index studies is that there is a small *instantaneous* relation between the forward scatter signal intensity and the accompanying weaker magnetic effects of the temperate latitudes. The effect has become so slight, compared with auroral path circuits, that it is only noticeable on integrated noon values. However, there is a marked daytime correlation on a monthly basis.

## VI. CONCLUSIONS

It has been established fairly definitely from a review of absorption results and rocket experiments that the electron concentration in the *D* region of the ionosphere changes with the 11-year solar cycle. Evidence for this change is strongly supported by a trend comparison of the temperate latitude forward scatter signal intensity values with the sunspot cycle values, and still more strongly by comparison with the magnetic disturbance indexes.

It is obvious, from off-great-circle path studies, that aspect-sensitive reflections from meteor trails must play a considerable part in forward scatter,[13–16] but the present work shows that solar influences are definitely contributing, especially for the midday period, to the magnitude of the received signal. McKinley's suggestion[25] that the results can be explained almost entirely on the basis of meteoric reflections is thus no longer valid. Villard, Eshleman, Manning, and Peterson[26] qualify the idea of exclusive meteoric ionization by considering that the general background excitation level may affect the extent of ionization produced by small meteors. This concept, if applied only to nonaspect sensitive reflections, cannot be ruled out,[15] but now it can be said that the sun exerts a specific effect on the magnitude of the daytime scatter signal.

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[25] D. W. R. McKinley, "Dependence of integrated duration of meteor echoes on wavelength and sensitivity," *Canad. J. Phys.*, vol. 32, pp. 450–467; July, 1954.

[26] O. G. Villard, V. R. Eshleman, L. A. Manning, and A. M. Peterson, "The role of meteors in extended range VHF propagation," Proc. IRE, vol. 43, pp. 1473–1481; October, 1955.

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# On the Determination of the Electrodes Required to Produce a Given Electric Field Distribution Along a Prescribed Curve*

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**Summary—A method is derived for determining the potentials in a space-charge-free region, with given potentials and electric fields on a prescribed curve. The treatment is two-dimensional. The method used is to set up a complex analytic potential function along the trajectory, which may be continued analytically into an open region, and whose derivative is related to the electric field.**

**The method is applied to two problems: that of the design of the electrodes for a crossed-field electron gun, and that of the design of the electrodes for Sturrock "leap-frog" focusing. It is shown that, owing both to the mathematical and the physical nature of the problems, care must be taken in the application of the method, in order to produce meaningful results.**

**The electrode shapes required to produce exactly the beams in each of the two problems are given. Electrode systems which would be easier to fabricate and which adequately approximate the required fields at the edges of the beam are also described.**

## I. Introduction

Many physical situations arise in which we desire to determine the electrodes required to produce a known electron trajectory—with specified potential and normal electric field on the trajectory.

In practice, the presence of the electrons is not relevant; we merely require to find equipotentials which will produce a given normal field and potential distribution along a prescribed curve. This field distribution cannot be described arbitrarily; it depends upon the solution of the space-charge-flow equations in the interior of the beam—a problem which we will assume already solved in this paper.

This problem has come to the author's attention in two different practical applications: in the design of electron guns, and the design of a deflection focusing system. The trajectories, in both instances, were planar, and all quantities were infinite in the third direction.

The problem is best illustrated in Fig. 1, which is a schematic of an electron gun. Here $K$ is the cathode, $D$ is the region of the beam, and $\Delta_1$ and $\Delta_2$ are space-charge-free regions outside the beam. The beam boundaries are $S_1$ and $S_2$. From knowledge of the electric fields on $S_1$ and $S_2$, we wish to determine the potentials $\Phi_1$ and $\Phi_2$ in the space-charge-free regions $\Delta_1$ and $\Delta_2$. If electrodes are placed at any equipotentials of $\Phi_1$ and $\Phi_2$, at the appropriate potentials, they produce the correct field and potential variation on $S_1$ and $S_2$. The focusing system problem is exactly similar, except that in this case $S_1 = S_2$, and the region $D$ does not exist.

There are basically three ways of solving this problem: analytic methods, analog methods, or a combination could be employed. Because of the nature of Laplace's equation with prescribed $\Phi$ and $\partial\Phi/\partial n$, the normal component of $\nabla\Phi$, on an open boundary, numerical solution into the regions $\Delta_1$ and $\Delta_2$ is very unstable. If the curves $S_1$ and $S_2$ are rectilinear, then $\partial\Phi/\partial n$ is 0, to be compatible with the Lorentz force law; Pierce[1] has

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† Microwave Lab., W. W. Hansen Labs. of Physics, Stanford University, Stanford, Calif.

[1] J. R. Pierce, "Rectilinear electron flow in beams," *J. Appl. Phys.*, vol. 11, pp. 548–554; August, 1940.

developed a method, using analytic continuation, to find $\Phi$ in $\Delta_1$ and $\Delta_2$ in this case. In this paper the analysis is extended to the case of when $S_1$ and $S_2$ are curvilinear, and $\partial\Phi/\partial n$ is no longer zero on these curves. The analog methods, as described by Sander,[2] for instance, use an analog such as an electrolytic tank with the electron beam simulated by current probes. Alternately, Pierce has developed an electrolytic tank method, for rectilinear $S_1$ and $S_2$, in which the curves are replaced by dielectrics—to satisfy $\partial\Phi/\partial n=0$ there. Cook[3] has extended these methods to the case of curvilinear $S_1$ and $S_2$ by placing resistance cards along the curves. Several other people, Picquendar[4] for example, have given methods of solving the problem with more or less elaborate analog equipment or numerical computation. An exact solution for $\Phi$ outside the beam would tell us where to put electrodes to produce the beam. Even if these proved difficult to fabricate, the solutions might allow the other methods cited to be used more simply. It is well known that since, in the absence of space charge, *i.e.*, in the regions $\Delta_1$ and $\Delta_2$ of Fig. 1,

$$\nabla^2\Phi = 0, \tag{1}$$

it is possible to make $\Phi$ the real part of a function $W$ of a complex variable $z$, where

$$W(z) = \Phi + i\Psi, \tag{2}$$

$$z = x + iy, \tag{3}$$

and $(x, y)$ are the normal Cartesian coordinates, $\Psi$ being defined by (2).

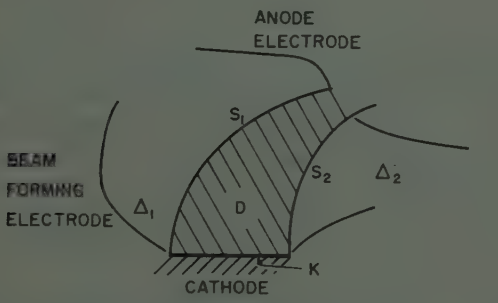

Fig. 1—Schematic of an electron gun.

We assume the electric fields on the trajectories $S_1$ and $S_2$ are given parametrically in terms of a real parameter $u$, and that $S_1$ and $S_2$ are themselves given parametrically. We then use the methods of analytic continuation to extend the values of the electric fields $\boldsymbol{E}$, known on $S_1$ and $S_2$, to the regions $\Delta_1$ and $\Delta_2$. For numerical convenience, we then derive a differential equation which must be satisfied by the equipotentials. Finally, we apply the methods to the two problems mentioned earlier, and give diagrams of the resulting electrode systems.

At first sight, it seems that the method is automatic, that it can be blindly applied, and that it always yields correct results. This is not the case. If sufficient care is taken, the method yields correct results. However, difficulties may arise from the multivalued nature of many of the conformal mappings encountered in the application of the method. This is made clear in the first example, that of the electron gun. The fact that multivalued potentials appear cannot be dismissed as simply due to the mathematical nature of the method; it has physical significance. This is clarified by the discussion in the first example. It is due to the fact that it may be physically impossible to produce certain potentials on the surfaces $S_1$ and $S_2$, unless the electrodes are fairly close to the surfaces. Moreover, for some problems, several electrodes may be required.

In Section II, the method is developed. In Section III, it is applied to an electron gun problem, and the difficulties encountered will be discussed. In Section IV the application of the method to a deflection focusing system is demonstrated. A summary of the pros and cons of the method, as illustrated by the applications, is given in Section V.

## II. METHOD

In this section, we consider half the problem mentioned in Section I, namely, given the potential and normal fields in terms of a parameter $u$ and a trajectory $S$ also given parametrically in terms of $u$, find the potential $\Phi$ in the semi-infinite region $\Delta$ bounded by $S$.

For the applications we have in mind, it is convenient to give the trajectories in an $(s, \psi)$ form, where $s$ is the arc length and $\psi$ the trajectory slope. For this reason, mappings are given relating the $(s, \psi)$ and the $(x, y)$ systems. The independent parameters will be $u$ and $v$ where the $(u, v)$ system is an orthogonal system having $v=0$ as the trajectory. All physical quantities are given as functions of $(u+iv)$. Quantities given on the trajectory as functions of $u$ are extended, by analytic continuation, to points off it as functions of $(u+iv)$.

We assume that the trajectory $S$ is planar and given in Cartesian coordinates $(x, y)$ by

$$x = X(u), \qquad y = Y(u). \tag{4}$$

Defining

$$z = x + iy, \tag{5}$$

and

$$Z(u) = X(u) + iY(u), \tag{6}$$

we may construct a conformal transformation

$$z = Z(w) \tag{7}$$

where

$$w = u + iv \qquad (u \text{ and } v \text{ are real}). \tag{8}$$

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[2] K. F. Sander, C. W. Oatley, and J. G. Yates, "Factors affecting the design of an automatic electron trajectory tracer," *Proc. IEE*, vol. 99, pp. 169–179; July, 1952.

[3] E. J. Cook, "Electrolytic tank design of electron guns with curved electron trajectories," PROC. IRE, vol. 46, p. 497; February, 1958.

[4] J. E. Picquendar, O. Cahen, and P. Lapostolle, "Les Effets de la Charge D'Espace dans les Cannons à Electrons," Compagnie Française de Thomas Houston, Paris; 1956.

This transformation maps points of the $w$ plane into points of the $z$ plane. In particular, considering $v=0$ in (6), we see that the transformation maps the $u$ axis into $S$. This mapping is shown in Fig. 2.

In the problem to be considered, $S$ is given as in (4), where $s(u)$ is the arc length measured along $S$. The $u=\text{const}$ lines are lines intersecting $S$ normally; this is shown in Fig. 3. We see that along $S$,

$$dx = ds \cos\psi \quad \text{and} \quad dy = ds \sin\psi, \tag{9}$$

where $\psi$ is the slope of the trajectory.

Comparing (9) with (4)–(6), we see that

$$dZ = e^{i\psi} ds,$$

so that

$$Z(u) = \int^{u} e^{i\psi} \frac{ds}{du'} du', \tag{10}$$

where

$$s = s(u) \quad \text{and} \quad \psi = \psi(u). \tag{11}$$

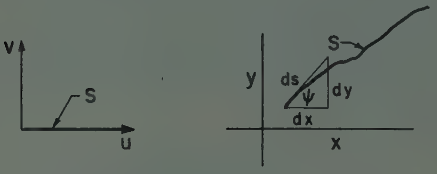

Fig. 2—Mapping of $w$ plane into $z$ plane.

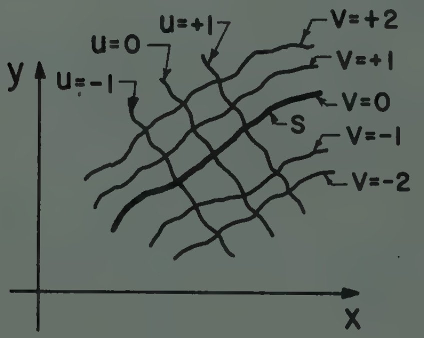

Fig. 3—Mapping of lines $u=\text{const}$ and $v=\text{const}$ in $z$ plane.

The lower limit in (10), and in any further similar integrals in this and the following section, is omitted. This lower limit merely corresponds to choice of origin in the $z$ plane. The question of lower limit is discussed in Section III.

Eq. (10) is in the form of (6). We may extend this function $Z$ to complex arguments, as we did in (7), so that we obtain a conformal mapping of the $w$ plane into the $z$ plane by the transformation

$$z = Z(w) = \int^{w} e^{i\psi(w')} \frac{ds(w')}{dw'} dw'. \tag{12}$$

Now if $\Phi$ is the scalar potential, we know both the magnitude and direction of $\nabla\Phi$ on $S$. Let us suppose the angle between $\nabla\Phi$ and $\boldsymbol{ds}$ is called $\theta(u)$, and let us define functions $\Phi_u(u)$ and $\Phi_v(u)$ by the relations

$$\Phi_u(u) = |\nabla\Phi| \cos\theta \frac{ds}{du} \quad \text{and} \quad \Phi_v(u) = |\nabla\Phi| \sin\theta \frac{ds}{du}. \tag{13}$$

Let $\Phi=\Phi(u, v)$ be the potential function throughout the $w$ plane, and hence, using (12), throughout the $z$ plane. Then, from (13), we obtain on $S$,

$$\Phi_u(u) = \frac{\partial\Phi}{\partial u} \quad \text{and} \quad \Phi_v(u) = \frac{\partial\Phi}{\partial v}. \tag{14}$$

Now we wish to construct an analytic function $W$, defined by

$$W = \Phi(u, v) + i\Psi(u, v), \tag{15}$$

which is analytic on $S$ and over most of the $w$ plane. In this case, the Cauchy-Riemann equations,

$$\frac{\partial\Psi}{\partial u} = -\frac{\partial\Phi}{\partial v} \quad \text{and} \quad \frac{\partial\Psi}{\partial v} = \frac{\partial\Phi}{\partial u}, \tag{16}$$

must hold wherever $W$ is analytic.

Using the first of (16) in (14), we see that on $S$

$$\frac{\partial\Phi}{\partial u} + i\frac{\partial\Psi}{\partial u} = \Phi_u(u) - i\Phi_v(u). \tag{17}$$

Integrating along $S$, which is the curve $v=0$, we obtain

$$W(u, 0) = \int^{u} \left[\frac{\partial\Phi}{\partial u'} + i\frac{\partial\Psi}{\partial u'}\right] du'.$$

$$= \int^{u} [\Phi_u(u') - i\Phi_v(u')] du'. \tag{18}$$

If a function satisfies one Cauchy-Riemann equation on the real axis it may be continued analytically into the plane away from that axis by replacing the real argument by the complex argument. Applying this to (18), we obtain

$$W(w) = W(u, v) = \int^{w} [\Phi_u(w') - i\Phi_v(w')] dw'. \tag{19}$$

Eqs. (12) and (19) give $z$ and $W$ as functions of $w$.

Finally, we set up the differential equation for the equipotentials. For this purpose we first neglect the fact that $\Phi$ is the real part of a function of a complex variable. We set up $v$ as a function of $u$ for the equipotential. Then we transform this curve in the $(u, v)$ plane into one in the $(x, y)$ plane.

If

$$v = V(u) \tag{20}$$

is the curve, $\Phi=\text{const}$, then along this curve

$$d\Phi = \frac{\partial\Phi}{\partial u} du + \frac{\partial\Phi}{\partial v} dV = 0. \tag{21}$$

Using the Cauchy-Riemann equations,

$$du \frac{\partial\Phi}{\partial u} - \frac{\partial\Psi}{\partial u} dV = 0. \tag{22}$$

Now, from (19), since $W$ is a function only of $w$,

$$\frac{\partial \Phi}{\partial u} + i\frac{\partial \Psi}{\partial u} = \Phi_u(w) - i\Phi_v(w) = \frac{dW}{dw}; \tag{23}$$

hence

$$\frac{dV}{du} = \frac{\operatorname{Re}(dW/dw)}{\operatorname{Im}(dW/dw)}. \tag{24}$$

The equipotentials of $W$, and hence the places where electrodes should be placed, may, therefore, be found by evaluating (12) along the contour defined by (24). It should be emphasized that slight changes in the functional form on $S$, of $\psi$, $s$, $\Phi_u$, and $\Phi_v$ as functions of $u$, may radically change the equipotentials, but this only affects the uniqueness of the electrodes. Any functional forms of these quantities which are almost correct on $S$ will produce satisfactory electrode systems.

## III. APPLICATION TO THE CROSSED-FIELD ELECTRON GUN

### *Statement of Problem*

Benham[5] and more recently Kino[6] have considered a certain planar, crossed-field, space-charge-flow problem, with magnetic field perpendicular to the plane of motion, in which the trajectory $S$ and the electric fields at the beam edge $\nabla\Phi$ satisfy the following relationships on the trajectories $S_1$:

$$E_x = 0; \tag{25}$$

and

$$X = \left[\frac{u^2}{2} + \cos u - 1\right],$$
$$Y = [u - \sin u]; \tag{26}$$

and

$$\Phi = \left[1 - \cos u + \frac{u^2}{2} - u \sin u\right]. \tag{27}$$

We now find the potentials in $\Delta_1$ of Fig. 1, outside $S_1$, by substitution of these equations into those of the previous section.

### *Expressions for Physical Quantities*

From (6) and (26),

$$Z(u) = \frac{u^2}{2} + iu + e^{-iu} - 1, \tag{28}$$

so that

$$Z(w) = \frac{w^2}{2} + iw + e^{-iw} - 1. \tag{29}$$

From (13),

$$\Phi_u - i\Phi_v(u) = |\nabla\Phi| e^{-i\theta}\frac{ds}{du}, \tag{30}$$

where $\theta$ is the angle between $\boldsymbol{ds}$ and $\nabla\Phi$.

Now, since $E_x=0$, from (25),

$$\nabla\Phi = \left(0, \frac{\partial\Phi}{\partial y}\right) \quad \text{and} \quad \theta = \frac{\pi}{2} - \psi. \tag{31}$$

From (30) and (31),

$$\Phi_u - i\Phi_v = -i\frac{d\Phi}{du}\frac{du}{dy}e^{i\psi}\frac{ds}{du}. \tag{32}$$

By some algebra, using (9), (26), and (27), (32) may be transformed into

$$\Phi_u - i\Phi_v = u(1 - iu - e^{-iu}). \tag{33}$$

Substitution of (33) into (19) now yields

$$W(w) = W(u, v) = \int^w w(1 - iw - e^{-iw})dw$$
$$= \left(-\frac{1}{3}iw^3 + \frac{w^2}{2} - iwe^{-iw} - e^{-iw} + 1\right), \tag{34}$$

where the constant of integration is taken as unity, so that $\Phi$, the real part of $W$, is in agreement with (27) on $v=0$.

Lastly, the equation of the equipotentials in the $(u, v)$ plane can be obtained from (24) and (33):

$$\frac{dV}{du} = \frac{\operatorname{Re}(w - iw^2 - we^{-iw})}{\operatorname{Im}(w - iw^2 - we^{-iw})}. \tag{35}$$

Eq. (35) has been solved on an IBM computer, using a standard program for solving differential equations. From its solution, we find

$$V = V(u) \tag{36}$$

for any equipotential, and we may then substitute the appropriate values of $(u, V)$ into (29) to trace out the equipotentials.

The results, and the difficulties which arise in their interpretation, are given in the following discussion.

### *Discussion of Results*

*Multivalued Mappings:* In order to discuss the results and the difficulties encountered, let us consider what we are doing when we follow equipotentials, what results we obtain, and where the difficulties occur.

From (29), (34), and (35) we obtain

$$z = Z(u + iV), \tag{29a}$$

$$W = W(u + iV), \tag{34a}$$

and

$$V = V(u). \tag{36}$$

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[5] E. Benham, "Electronic theory and the magnetron oscillator," *Proc. Phys. Soc., London*, vol. 47, pp. 1–53; January, 1935.

[6] G. S. Kino, private communication.

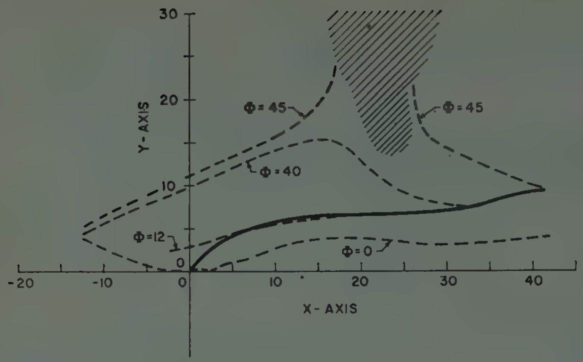

Fig. 4—Equipotential plots in the $z$ plane for the electron gun problem. The solid line is the electron trajectory; the dotted lines are equipotentials, with the numbers representing normalized potentials. The shaded area is the region of multivalued potentials.

Now, if, as happens in this case, $Z=Z(w)$ is a multivalued mapping of the $w$ plane into the $z$ plane, then different values of $(u, v)$ may result in the same $(x, y)$. Now, from (35), we may obtain the pair of points $(u_1, v_1)$ and $(u_2, v_2)$ which give the same $z_0$, but different $\Phi$. Then we have, apparently, multivalued potentials at this point $z_0$, which is clearly physically impossible.

For the problem we are solving to have any meaning, there must be a one-to-one correspondence between the points of the line $v=0$ of the $w$ plane and points in both the $w$ and the $z$ planes. In that case, since $W(w)$ and $Z(w)$ are regular functions of $w$, there must exist a region, sufficiently close to $v=0$, in which such a one-to-one correspondence still holds.

An example will illustrate this point. Suppose

$$W = 2iw + e^{2iw} \tag{37}$$

and

$$Z = e^{iw}. \tag{38}$$

Then on $v=0$, the trajectory,

$$\Phi = 0,\ Z = e^{iu},\ \text{and}\ E_{\text{normal}} = 4\cos^2 u. \tag{39}$$

If $w$ is not zero, and $u$ is increased by $2\pi$, a different $\Phi$ will result. Hence, the mapping must be restricted to $0<u<2\pi$.

However, in following an equipotential, one would find that one must continue beyond $u=2\pi$, and so multivalued potentials arise. When this occurs, it means that the physical system cannot be realized with only one electrode of the type envisaged. This occurred in the problem we are considering.

A graph of the equipotentials is shown in Fig. 4. It is seen that there is no trouble below the trajectory $v=0$, that is, for $v<0$. However, for $v>0$, there is a shaded area. In this area, the potential would be multivalued. This means that electrodes must be placed between this region and the trajectory to obtain the required potential and field variation on the trajectory.

From a mapping of the $z$ plane into the $w$ plane, which is shown in Fig. 5, we see where the forbidden zone arises.

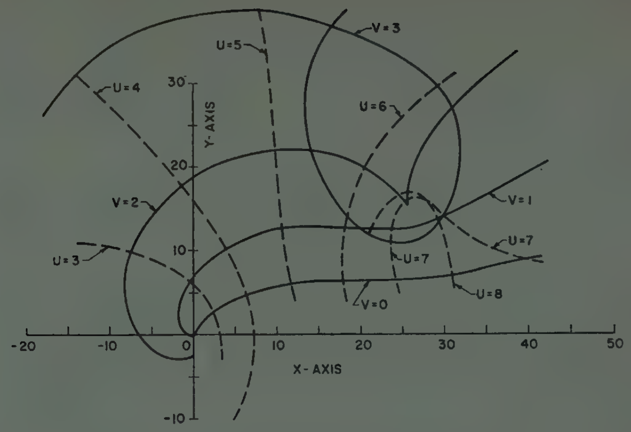

Fig. 5—Mapping of the $w$ plane into the $z$ plane for the electron gun problem. The solid lines represent $v=$const, the broken lines, $u=$const.

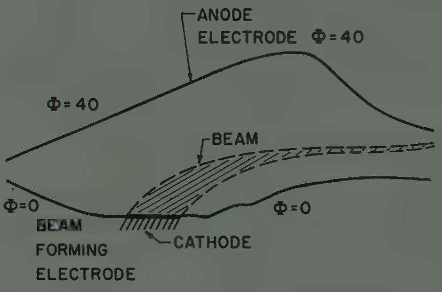

Fig. 6—Electrode system to produce the beam from the crossed-field electron gun.

## IV. Application to Gun Design

In the actual gun design problem, the $S_1$ and $S_2$ of the gun were merely displaced by a constant $x$; that is, on $S_1$,

$$Z(u) = \left(\frac{u^2}{2} + iu + e^{-iu} - 1\right); \tag{28}$$

while on $S_2$,

$$Z(u) = \left(\frac{u^2}{2} + iu + e^{-iu} - 1\right) + X_0, \tag{28a}$$

where $X_0$ is a real constant. The region between the two curves $S_1$ and $S_2$ is occupied by the beam. Hence, the solutions for $v>0$ of Fig. 4 are valid in $\Delta_1$ of Fig. 1, while those of $v<0$ are valid, under shift of origin, in $\Delta_2$ of Fig. 1. The resulting electrodes and beam configurations are shown in Fig. 6.

## V. Application to Deflection Focusing

### *Statement of Problem*

Sturrock[7] has considered a problem in periodic deflection focusing which he calls "leap-frog" focusing. In a focusing system it is convenient to relate the momentum, radius of curvature, normal field, and angle of the trajectory. In his system, Sturrock has shown that, on one period of $S$,

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[7] P. Sturrock, private communication.

$$\frac{ds}{du} = e^{-\psi_0 \sin u} \tag{40}$$

$$\psi = \psi_0 \cos u, \tag{41}$$

$$\theta = -u, \tag{42}$$

$$\Phi = \frac{1}{2\psi_0} e^{2\psi_0 \sin u}, \tag{43}$$

and

$$|\nabla\Phi| = e^{3\psi_0 \sin u}. \tag{44}$$

*Mathematical Expressions*

Substitution of (40) and (41) into (12) yields

$$\begin{aligned} Z(w) &= \int^{w} e^{i\psi_0 \cos w'} e^{-\psi_0 \sin w'} dw' \\ &= \int^{w} e^{i\psi_0 \exp iw'} dw', \end{aligned} \tag{45}$$

while substitution of (42) and (44) into (13) and (19) yields

$$\begin{aligned} W(w) &= \int^{w} e^{3\psi_0 \sin w'} e^{iw'} e^{-\psi_0 \sin w'} dw' \\ &= \int^{w} e^{2\psi_0 \sin w'} e^{iw'} dw'. \end{aligned} \tag{46}$$

In the same way as previously, the simultaneous evaluation of (45) and (46) will give a mapping of the $w$ plane into the $z$ plane. Again, to obtain the equipotentials, it is necessary to follow, from (24) and (46), the contour

$$\frac{dV}{du} = \frac{\operatorname{Re}\,(e^{2\psi_0 \sin w} e^{iw})}{\operatorname{Im}\,(e^{2\psi_0 \sin w} e^{iw})}. \tag{47}$$

The mappings are again multivalued, but this time the mapping of the $w$ plane into the $W$ plane is multivalued, *i.e.*, different $w$ produce the same $W$, but the mapping from the $w$ plane into the $z$ plane is not multivalued. Hence the multivalued nature of the mapping will cause no problem. The lower limit of integration is arbitrary. It merely determines the zero point of potential in the $z$ plane. We desire that the origin of $z$ coordinates be at the lowest potential point of the trajectory; this determines the constant of integration, so that (46) becomes

$$W = \frac{1}{2\psi_0} e^{-2\psi_0} + \int^{w} \exp\,(iw' + 2\psi_0 \sin w')dw'. \tag{48}$$

Since neither $z$ nor $W$ have poles or singularities in the finite part of the $w$ plane, there is no possible source of error through calculating the integrals the wrong way round a pole or branch point—this could be a problem otherwise. However, from (46), $W$ has a singularity, in fact, an isolated essential singularity, at $\pm\infty i$. On the other hand, $z$ from (45) has a singularity at $-\infty i$. Hence, something strange will occur as $w \rightarrow \infty i$, especially since the singularity of $W$, at $\infty i$, is an essential singularity.

From (45), since the path of integration may be taken arbitrarily, at $w = \infty i$,

$$z = \int^{\infty} e^{i\psi_0 \exp(-v')} i\,dv'. \tag{49}$$

Eq. (49) gives a definite point in the $z$ plane at which an isolated essential singularity of $W$ will result. Since the whole system is periodic this singularity will be repeated every periodic length of the deflection system. This shows up in (49), if we consider not the point $\omega = \infty i$ but $w = u + \infty i$. Then for $-\pi < u_0 < \pi$, one obtains one $z$, namely $Z_0$; for $(2n-1)\pi < u < (2n+1)\pi$, one obtains $Z_n = Z_0 + nL$, where $L$ is the periodic length of the system, defined from integrating (44) along one period, and taking its real part,

$$L = \operatorname{Re} \int_0^{2\pi} e^{i\psi_0 \exp iu'} du'. \tag{50}$$

With the explanation already given we may now understand the reasons for the equipotential plots resulting from the integration of (45) along the contours defined by the solution of (46). This is shown in Fig. 7 for one particular $\psi_0$, $\psi_0 = \frac{1}{2}$. It is seen that in this case there are no forbidden regions, unlike the previous example. However, there is one point periodically placed through which all equipotentials pass. The fact that all potentials go through this point is a result of the essential nature of the singularity of $w$ at $\infty i$ in the $w$ plane.

Fig. 7 is the exact electrode system which would be necessary; however, a system like that of Fig. 8 would, at $S$, be a sufficiently good approximation for a focusing system with very similar characteristics to the one defined by (40) through (43).

## VI. SUMMARY OF THE POTENTIALITIES OF THE METHOD AND ITS PITFALLS

The method gives possible electrode configurations to solve any problem of the form of Fig. 1. However, if the mapping of the $w$ plane into the $z$ plane is multivalued, care must be taken in using the solution of the differential equation of (24). In actual computation, it is then necessary to look into the details of the $w$-$z$ and $w$-$W$ mappings.

It may require many electrodes to produce a given field pattern on the $S$; this is shown in the first example. It may not be possible to design the sytem if the proviso is added that the electrodes must be further than a certain distance from $S$. Finally, if there are singularities of $z$ or $w$ at finite points of the $w$ plane, a case not illustrated in this paper, it is necessary to make a cut in the $w$ plane to insure that the path of integration never completely surrounds a singularity. With this

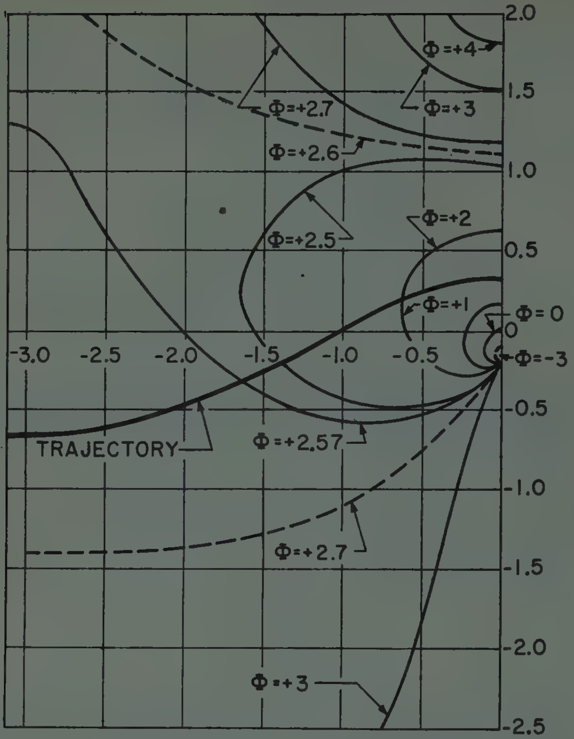

Fig. 7—Equipotential plots for "leap-frog" focusing for $\psi_c=\frac{1}{2}$. The heavy line represents the electron trajectory, while the solid and broken lines represent equipotentials. A possible electrode system would be given by the dotted lines $\Phi=2.6$, $\Phi=2.7$, and $\Phi=-3.0$.

proviso, the path of integration in the $w$ plane is always arbitrary.

In conclusion, it has been brought to our attention, since the writing of this paper, that R. J. Lomax[8] of Cambridge University has recently developed the method of analytic continuation independently. His approach, which has appeared elsewhere, is slightly different. Moreover, the application he gives is very different, and he does not discuss the difficulties which may arise in the application of the method. For these reasons we have decided to present this paper in its entirety.

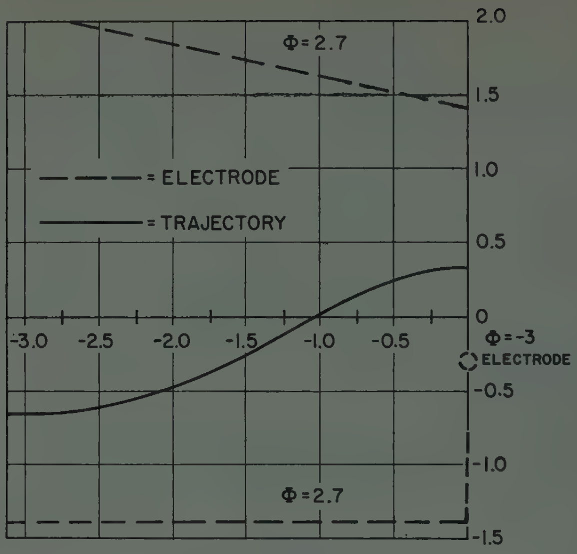

Fig. 8—An electrode system which approximates the system of Fig. 7 for "leap-frog" focusing.

## ACKNOWLEDGMENT

The author wishes to express his thanks both to Dr. G. S. Kiho and to Dr. P. A. Sturrock, who suggested the application of the method to the crossed-field electron gun and the "leap-frog" focusing system. Dr. Kino did much of the analysis of Section III.

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[8] R. J. Lomax, "Exact electrode systems for the formation of an electron beam," *Brit. J. Electronics and Control*, vol. 3, pp. 367–374; October, 1957.

# A Voltage-Sensitive Switch[*]

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**Summary—An investigation of the controlled dielectric breakdown of aluminum oxide films resulted in the development of a voltage-sensitive switch which may replace thyratrons and gas diodes in circuits which require single switching from a resistance in the kilomegohm range to one of the order of 1 ohm or less. Compared with a thyratron, the switch is smaller, less expensive, more resistant to shock, vibration and high-energy radiation, and requires no additional power supply. In a recent batch, all samples tested broke down between 12 and 13 volts dc.**

**Three circuits are presented which show applications of the switch in a time delay, in a series arrangement, and in a biasing network where terminal voltage is greater than the critical breakdown voltage of the switch.**

## INTRODUCTION

EXPERIMENTAL work at the Diamond Ordnance Fuze Laboratories (DOFL) on a new solid-state switching device was originally stimulated by an intelligence report[1] on the development of an over-voltage relay at the Forschungsinstitut für Physik in Berlin. However, no details of the construction and the performance of this German device became known to the personnel of these laboratories.

Approximately six months after the start of experimental work at DOFL, Kelly[2] applied for a patent which was assigned to the International Business Machines Corporation. This patent covered an "Information Storage Unit" which employed a metallic-oxide film-type device having a structure similar to that of the voltage-sensitive switch described in this paper.

Shortly thereafter, a report[3] was issued by the University of Arkansas which described somewhat similar work done there for a different purpose. However, their reported data indicated that less close control of the breakdown of a dielectric layer had been achieved at the University of Arkansas than at DOFL. For example, at approximately comparable average breakdown voltages, their smallest standard deviation was 2.90 while that at DOFL was 0.35.

The voltage-sensitive switch developed in these laboratories is based on the controlled dielectric breakdown of a thin oxide film formed electrolytically on a suitable metal, such as aluminum, tantalum or niobium. This solid-state component may replace thyratrons and gas diodes in circuits in which a single switching from a high blocking resistance to a low-resistance current path is required. Basically, the switch has the structure of an electrolytic capacitor. As in a capacitor, the dielectric oxide layer is located between two layers of metal: 1) the metal base, usually aluminum, which forms one electrode, and 2) a conductive film, in this case silver, which forms a second electrode. As in a capacitor, the thickness, and consequently the breakdown voltage, of the dielectric oxide layer is determined by the conditions under which it has been formed in the electrolytic bath. However, unlike an electrolytic capacitor, which is always operated below its breakdown voltage, the switch functions at the voltage at which the dielectric film breaks down.

Field strengths of the order of $10^7$ volts per centimeter[4] exist in thin anodic oxide films. It is known[5] that, even at lower field strengths, avalanche breakdowns occur in localized spots within these films. Imperfections in the oxide layer are the most likely locations for such breakdowns which may set in at voltages well below the breakdown potential of a perfect oxide film. Heterogeneities in the metal surface,[6] as well as impurities in the metal,[7] are defects which may cause irregularities in the structure of the oxide layer, and it has been observed[8] that the porosity of electrolytically formed aluminum oxide films is inversely related to the smoothness of the metal surface.

Since the quality requirements for the metallic foil and for the oxide film formed on its surface are much more stringent in the case of the voltage-sensitive switch than in that of an electrolytic capacitor, the purest metal foil with the smoothest surface was required for the production of dielectric oxide films having controlled and uniform breakdown properties.

This paper describes experimental work leading toward the development of a small switch, an example of which is shown in Fig. 1 in exploded and assembled form. This switch is composed of only three parts: 1) an anodized metal disk to which a silver electrode has been applied, 2) a pair of lead wires, one of which is soldered to the silver electrode and the other of which is connected to the base metal by means of a rivet, and

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[*] Original manuscript received by the IRE, March 5, 1958; revised manuscript received, June 30, 1958.

[†] Diamond Ordnance Fuze Labs., Washington, D. C.

[1] ID Rep. 1,196,582; November 25, 1953.

[2] M. J. Kelly, "Information storage unit," U. S. Patent No. 2,784,389 to IBM; March 5, 1957.

[3] Z. V. Harvalik, Univ. of Arkansas, Inst. of Sci. and Tech., Fayetteville, Ark., Final Rep. under Contract NOrd 10417; June 1, 1949 to May 31, 1955 (unclassified).

[4] A. Güntherschulze and H. Betz, "Elektrolytkondensatoren," Herbert Cram, Berlin, Ger., 2nd ed.; 1952.

[5] P. F. Schmidt, "Mechanism of electrolytic rectification," *J. Electrochem. Soc.*, vol. 104, p. 66C; March, 1957.

[6] D. A. Vermilyea, "Nucleation of crystalline tantalum oxide during field crystallization," *J. Electrochem. Soc.*, vol. 104, p. 542; September, 1957.

[7] D. Altenpohl, "Improvements in the field of electrolytic capacitors," 1954 IRE CONVENTION RECORD, pt. 3, pp. 35–39.

[8] G. S. Vozdizhenski, S. S. Valeev, and T. N. Grechukhina, "Anodic oxidation of a metal with texture," *J. Phys. Chem., USSR*, vol. 25, p. 87; 1951. Quoted in S. Wernick and R. Pinner, "Surface Treatment and Finishing of Aluminum," Robert Draper, Ltd., Teddington, Eng., p. 376; 1956.

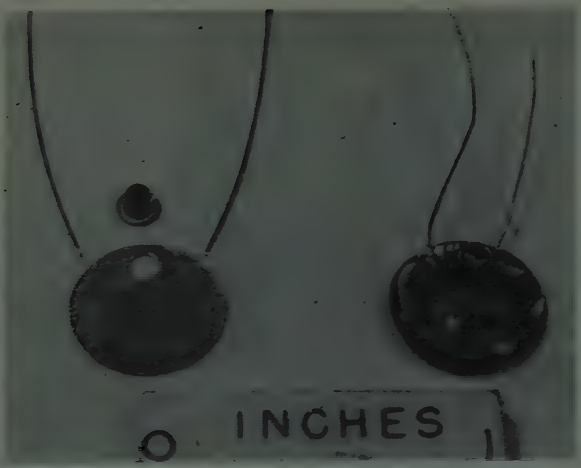

Fig. 1—Voltage-sensitive switch, unassembled and assembled.

3) this rivet, which is considered the most practical device for contact to the base metal in view of the strong adherence of the oxide film to its base. This paper further describes the properties of such a switch when made from anodized aluminum; it also shows that before breakdown the device has a resistance of at least $10^7$ ohms (in most cases $10^9$ to $10^{12}$ ohms) and that upon application of a pulse exceeding a certain critical voltage the switch breaks down to a resistance of the order of 1 ohm or less. The paper also describes some circuits in which a switch of this type has been employed.

### Preparation of Oxide Films

Use of tantalum as the base metal had been suggested by the fact that, in the commercial production of electrolytic capacitors, the replacement of an aluminum by tantalum anode had resulted in improved capacitors due to the greater chemical inertness of tantalum oxide compared with that of aluminum oxide. The oxidation of tantalum sheet was attempted first in a stream of oxygen, following essentially the procedure described by Gulbransen and Andrews.[9] However the oxide films produced were rough and unsuitable for breakdown switches.

Next, tantalum, niobium, and aluminum strips were anodized in numerous electrolytes, in an effort to find a metal and an electrolyte which would produce a uniform oxide film. These electrolytes included sulfuric acid, chromic acid, borates, tartrates,[10] and citrates.[11] Some of the various combinations of electrolytes and metals that were tested are listed in Table I, together with the electrolyte resistivities calculated for 25°C.

TABLE I

Electrolytes and Metals Used in Anodizing Experiments

| Electrolyte | Concentration of electrolyte | Resistivity of electrolyte, ohms | Metals anodized |
|---|---|---|---|
| Chromic acid | 6 g $CrO_3$+94 g $H_2O$ | 5.6 | Al |
| Chromic acid | 3 g $CrO_3$+97 g $H_2O$ | 10.6 | Al |
| Sulfuric acid | 0.1 per cent by volume | 106 | Ta, Nb |
| Sulfuric acid | 1 per cent by volume | 13.1 | Ta, Nb |
| Sulfuric acid | 2 per cent by volume | 7.1 | Ta |
| Sulfuric acid | 3 per cent by volume | 5.1 | Ta |
| Sulfuric acid | 5 per cent by volume | 3.0 | Ta |
| Sulfuric acid | 10 per cent by volume | 1.9 | Al, Ta, Nb |
| Borate | 10 per cent $B_2O_3$+2.5 per cent borax | 174 | Al |
| Glycoborate | 1 pt. $NH_4HB_4O_7 \cdot 3H_2O$<br>4 pt. glycol+4 pt. $H_2O$ | 144 | Al |
| Tartrate | 3 per cent acid+$NH_3$; pH=5.5 | 45 | Al, Ta, Nb |
| Citrate | 3 per cent acid+$NH_3$; pH=6.0 | 315 | Al, Ta, Nb |

When commercial tantalum or niobium was used as the base metal, none of the oxide films produced was as uniform as desired for use in a breakdown switch. In contrast, several baths were found suitable for the preparation of a satisfactory oxide layer on pure aluminum. Among these baths, a 6 per cent solution of chromic oxide in water produced an aluminum oxide film having more uniform breakdown strength than any other dielectric film tested during this investigation.

The results of these anodizing experiments are in line with those of an experimental study which was carried out almost simultaneously in England. There Huddle and Anderson[12] found that among the various electrolytic baths they tested chromic acid produced the most stable oxide films on aluminum. These authors also give a theoretical explanation for their findings. Following Weyl's theory of counter-polarization,[13] they point out that when chromate ions are absorbed on the surface of aluminum oxide, the relatively small and highly charged $Cr^{6+}$ central cations set up a more asymmetrical force field in the $O^{2-}$ ions contained in the $CrO_4^{2-}$ ions than would the central cations in any comparable anions; also, when polarization of these $O^{2-}$ ions is overcome by the counter-polarization of the oxide surface, the $O^{2-}$ ions are donated to the oxide film, thus promoting the growth of this film rather than its contamination or hydration, as is the case in some other electrolytes.

Earlier, Pullen[14] had found that aluminum oxide films prepared by anodization of highly pure aluminum in chromic acid were less contaminated through absorption of ions from the electrolytic bath than films produced from less pure aluminum and/or baths of sulfuric acid or oxalic acid. Pullen's, as well as Burnham's,[15] X-ray diffraction studies confirmed Verwey's[16] and Belwe's[17] findings that the anodization of pure aluminum in chromic acid resulted in practically anhydrous $\gamma$-$Al_2O_3$. Several investigations[18–21] have shown that the aluminum oxide hydrate and aluminum hydroxide which form through the absorption of water by the hygroscopic aluminum oxide do not have the favorable dielectric properties of anhydrous gamma aluminum oxide. In a study of bath concentrations, Buzzard[22] had found chromic acid solutions of 5 to 10 per cent strength most suitable for the production of corrosion resistant coatings on aluminum.

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[9] E. A. Gulbransen and K. F. Andrews, "Reactions of zirconium, titanium, columbium and tantalum with the gases oxygen, nitrogen and hydrogen at elevated temperatures," *J. Electrochem. Soc.*, vol. 96, p. 364; December, 1949.

[10] G. Hass, "On the preparation of hard oxide films with precisely controlled thickness on evaporated aluminum mirrors," *J. Opt. Soc. Amer.*, vol. 39, p. 532; July, 1949.

[11] W. Walkenhorst, "A simple procedure for the production of aluminum oxide layers," *Naturwissenschaften*, vol. 34, p. 373; August, 1947.

[12] R. A. U. Huddle and P. J. Anderson, "A catalytic mechanism of anodic inhibition in metallic corrosion," *Advances in Catalysis*, Academic Press, N. Y., vol. 9, p. 393; 1957.

[13] W. A. Weyl, Pennsylvania State Coll., School of Mineral Industries, State College, Pa., Bull. No. 57, 1951.

[14] N. D. Pullen, "Some physical characteristics of oxide films on aluminum," *J. Electrodepositors Tech. Soc.*, vol. 15, p. 69; 1939.

[15] J. Burnham, "Dielectric films in aluminum and tantalum electrolytic and solid tantalum capacitors," IRE Trans. on Component Parts, vol. CP-4, pp. 73–82; September, 1957.

The anodization of pure aluminum foil in 6 per cent chromic acid solution was the process chosen for the preparation of voltage-sensitive switches. Fully annealed ("dead soft") aluminum foil had to be used because the oxide film obtained on unannealed ("full hard") material was so porous that its insulation resistance could not even be measured.

Foil of 99.87 per cent purity proved to be unsatisfactory, but foil of 99.97 per cent minimum purity was found acceptable. Attempts to use 99.99 per cent pure foil which had been etched for use in capacitors resulted in complete failure. Although it had been reported[7] that superior capacitors had been made using this foil, its rough surface, which resulted from the etching, evidently precluded the formation of a uniform oxide film on its exterior. Sufficiently smooth foil of guaranteed 99.99 per cent purity was not available at the time of these experiments. At present, a purity of 99.97 per cent is considered a minimum requirement.

Efforts to improve the smoothness of commercial aluminum foil by polishing were unsuccessful. Various methods of polishing the foil mechanically were found impractical. Aluminum foil which had been electropolished in a mixture of nitric acid and methanol produced a porous oxide film, as did tantalum sheet which had been electropolished in a mixture of hydrofluoric and hydrochloric acids.[23]

In an effort to produce a very smooth layer of aluminum, thin aluminum films were prepared by vapor deposition on the polished surfaces of glass slides. However, even when these films were deposited in multiple layers, all the oxide coatings obtained on the films were found to have a sufficient number of pinholes such that a number of short contacts occurred when an electrical potential was applied to them. However, aluminum oxide films of sufficient quality for use in a study of their dielectric breakdown had been prepared by a similar method elsewhere.[24]

Attention was directed next to determination of the most favorable electrical conditions for the anodization. Formation at constant voltage was found satisfactory if a series resistor was inserted to eliminate the current spike which would otherwise occur during the first few seconds of formation of the oxide film, and before it was thick enough to limit the current. A bath temperature of 100°F was found suitable for this reaction. Lowering the temperature to 75°F resulted in a porous oxide film; raising it to 130°F produced a less uniform oxide layer.

The anodizing procedure and the aluminum foil which were shown to give optimum results were employed in the work described in the next section, which outlines the present procedure for producing finished switches.

## PROCEDURE FOR SWITCH PREPARATION

Fig. 2 shows the step-by-step preparation of the voltage-sensitive switches of which several thousand have been made to date. Aluminum foil, 0.0035 inch in thickness, at least 99.97 per cent pure, and of good surface smoothness, was cut into strips seven inches long and ½ inch wide. The strips were degreased in perchloroethylene which contained an amine stabilizer; they were then dipped in benzene, and finally dipped in acetone [see Fig. 2(a)].

The strips were then electrolytically oxidized in an apparatus which consisted of the following parts: 1) a 3000-cc beaker, 2) a plastic lid, 3) a brass clamp fastened on top of the plastic lid, 4) a polystyrene clamp hung from the plastic lid in a position near the bottom of the beaker, 5) two sheets of aluminum, also hung from the plastic lid, and 6) a motor-driven glass stirrer and a thermometer inserted through slots in the plastic lid. One end of each of four aluminum strips was fastened in the brass clamp; the lower end was fastened in the polystyrene clamp, thus assuring reproducible positioning of the strips. The four strips, connected in parallel, were made the anode; the two sheets of aluminum placed on either side of the strips, served as cathode in the forming circuit. The beaker was filled with chromic acid in the form of a 6 per cent solution of chromium trioxide in water. This bath was kept at 100°F by means of a heating mantle which completely surrounded the beaker. Temperature variations in the bath were limited to ±0.5°F. A potential of 20 volts was applied for 10 minutes by means of a dc power supply. A limiting 27-ohm resistor was placed in series

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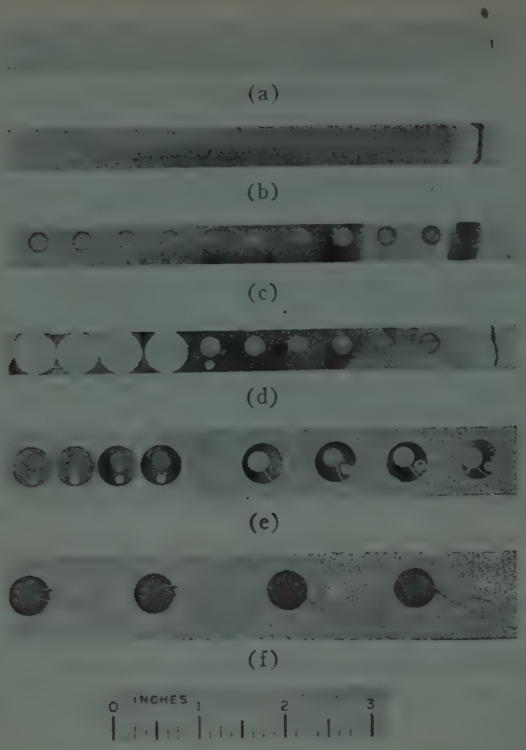

Fig. 2—Step-by-step preparation of voltage-sensitive switches. (a) Solvent-cleaned metal strip. (b) Anodized strip. (c) Strip with ten silver electrodes. (d) Strip after punching four disks. (e) (*left*) Four disks; (*right*) same, with leads. (f) Four switches, resin dipped.

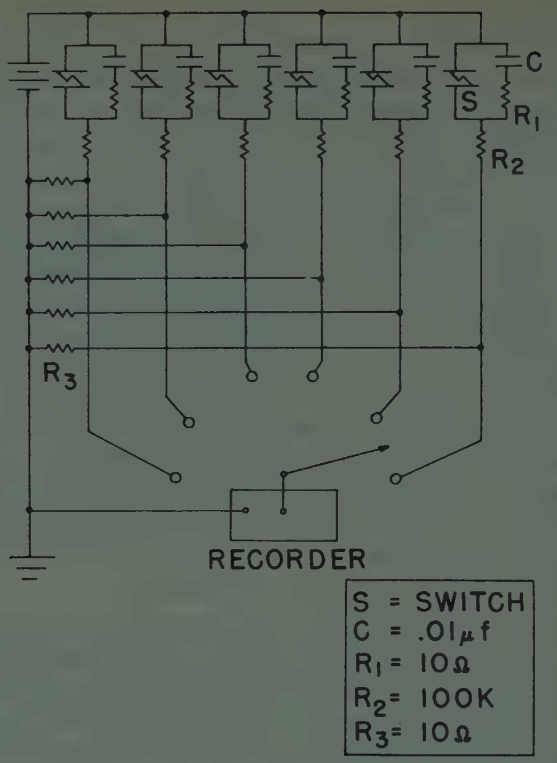

Fig. 3—Circuit for testing the breakdown behavior of switches under a sustained potential.

with the strips. An anodized metal strip is shown in Fig. 2(b).

Immediately after the end of the electrolytic oxidation, the strips were thoroughly washed with water, then with acetone, and dried for two days at 105°C. Ten circular silver electrodes having a diameter of $\frac{1}{4}$ inch were then applied to each strip, as shown in Fig. 2(c), by using a "silk"-screening process; the strips were again dried at 105°C for two days.

Ten silvered anodized aluminum disks were then punched out of each strip by means of a punch which produced in one operation a disk and a rivet hole in the adjoining disk, as seen in Fig. 2(d) and 2(e). A metal rivet with a copper wire twisted around it was crimped into the rivet hole, and another copper wire was soldered to the silver electrode. The switches were given mechanical support, as well as some protection from the atmosphere, by being dipped into an epoxy resin coating which was cured first at 60°C, then at 100°C. Finished switches are shown in Fig. 2(f).

In recent experiments silver electrodes having a diameter of $\frac{1}{8}$ inch, rather than $\frac{1}{4}$ inch, were applied to the anodized aluminum strips in various geometric patterns. In this way the over-all size of the switches was reduced and a larger number of samples was obtained from each strip.

## Electrical Testing of Switches

Since the switch is a polar device whose stability is based on the strong affinity of aluminum to oxygen, the aluminum foil was made the anode not only in the forming process but also in all circuit applications, including the test circuit used to measure the breakdown voltage of the switches. The silver electrode was made the cathode in the test circuit. A gradually increasing dc potential was applied to the switch, and the voltage at which breakdown occurred was observed.

In addition to the tests in which the breakdown under a dc pulse was determined, breakdown tests under a sustained dc potential were also performed. Fig. 3 shows the circuit used for the simultaneous testing of six switches under a sustained dc potential. This apparatus assures that the voltage applied to any of the six switches under test will remain the same if one or more of the switches break down. Partial breakdowns and subsequent healing of switches were automatically recorded by this method.

Two groups of breakdown tests were conducted by the application of sustained potentials. In one, the test potential was maintained continuously; in the other, cycling—a 15-second interruption after every 60 seconds of operation—was achieved with the aid of a timer.

## Results of Tests

Fig. 4 compares the distributions of breakdown voltages of aluminum oxide films obtained at the beginning and at the end of the experimental study of the electrolytic oxidation of aluminum in a bath of chromic acid. The spread of breakdown voltages had been from 12 to 60 volts at the beginning of this study, but all switches broke down between 12 and 13 volts at the end of these experiments, which resulted in the anodizing method

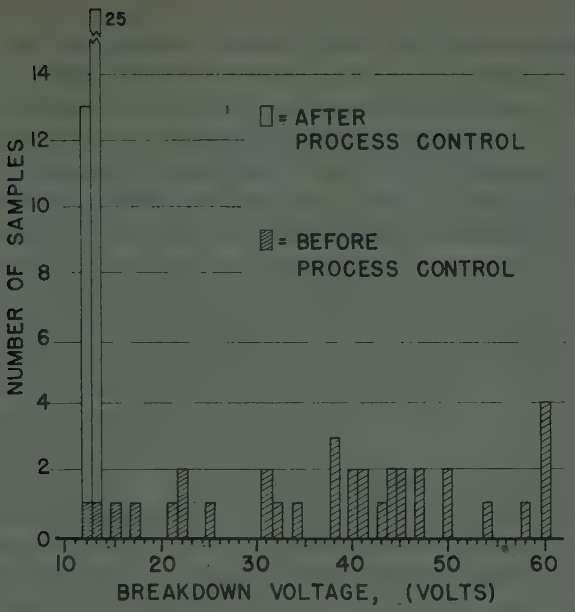

Fig. 4—Distribution of breakdown voltages before and after an experimental study of the anodization of aluminum in chromic acid.

described in the section "Procedure for Switch Preparation."

Switches with $\frac{1}{4}$-inch-diameter electrodes had a capacitance of about 2000 $\mu\mu$f and a dissipation factor of 1 to 2 per cent, when measured at 1000 cps with a bias of a few volts. The capacitance of switches having $\frac{1}{8}$-inch diameter electrodes should be only 500 $\mu\mu$f, which would be an added advantage for some applications.

Resistance measurements showed that all switches tested had a resistance of at least $10^7$ ohms before breakdown, usually $10^9$ to $10^{12}$ ohms. Resistance after breakdown was of the order of 1 ohm, in many cases, a few tenths of an ohm.

The narrow spread in breakdown voltages which has been obtained indicates the high degree of purity of the aluminum oxide layers which have been prepared and the close control which has been achieved over the breakdown behavior of the dielectric films. In addition, these oxide layers retained their uniform breakdown properties even in the dry state and in the absence of any liquid or solid electrolyte of the kind which assures the rehealing of the dielectric oxide film in electrolytic capacitors.

In a study of the effect of varying temperatures on the breakdown voltage of the switches, it was observed that the average breakdown voltage at −60°C was about 14 per cent higher than at room temperature; at 100°C, about 16 per cent lower. The spread among the values measured was also higher at −60°C, and lower at 100°C, than at room temperature.

The effect on the breakdown voltage of a high impedance placed in series with the switch was also studied. No significant effect was observed if the series resistance did not exceed 10,000 ohms. An increasing number of incomplete and multiple breakdowns occurred if greater resistances were placed in series.

A study of the effect of the rise time of the breakdown pulse on the breakdown voltage of the switch showed that the latter was practically independent of the rise time for periods longer than about 10 milliseconds. Breakdown voltages measured with pulses of 1 to 5 microseconds were about 80 per cent higher than those which had been observed with pulses which were longer by at least 4 orders of magnitude.

Under all conditions tested, the breakdown was completed in less than 1 microsecond. This value is in line with that given in the literature[25] for the electric breakdown of solid dielectrics.

The switch remained unaffected after breakdown if peak currents of several amperes were passed through it. However, it could be reopened if the bias was removed and a dc current of about $\frac{1}{2}$ ampere then passed through. In this manner, up to about 80 consecutive breakdowns at fairly constant voltage levels could be accomplished with one switch. The possibility of using the switch more than once, under certain conditions, was demonstrated by these experiments. However, the control achieved over repeated breakdowns of one switch was much less close than that over the single breakdown of several switches, and the switch must be considered primarily a one-time-use device.

The breakdown behavior under a sustained potential was studied on a group of switches which, under a dc pulse, had a distribution of breakdown voltages ranging from 12.5 to 15.5 volts. On the basis of the test results, it may be concluded that this batch of switches should not be subjected to a sustained potential of more than about 9 volts if breakdown is to be avoided. Thus, an additional dc signal of 3.5 to 6.5 volts on top of this bias would be required for the breakdown of these switches.

Many of the breakdowns which occurred under sustained potentials of 10 volts or more happened during the first minute of operation. However many of these breakdowns were incomplete, and the switches could be operated at a reduced insulation resistance for several hours after their early partial breakdown.

Storage tests showed successive decreases in the breakdown voltage of the switches after 140 days and 240 days of storage at room temperature. Table II shows that these decreases were greater after storage in the atmosphere than in a desiccator. This effect can well be the result of the absorption of water by the insufficiently protected aluminum oxide layer. It has been pointed out earlier that anhydrous aluminum oxide has dielectric properties superior to those of hydrated materials. The storage characteristics of the switch, therefore, depend on its protection from the moisture of the atmosphere. A thicker coating of epoxy resin has been applied to more recent batches of switches. These switches, therefore, should show improved storage

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[25] W. Rogowski, E. Flegler, and R. Tamm, "On travelling waves and breakdown," *Arch. Elektrotech.*, vol. 18, p. 479; June 27, 1927.

TABLE II

Dependence of the Breakdown Voltage of Voltage-Sensitive Switches on Storage Time

| Storage time, days | Stored in a desiccator | | | Stored in the atmosphere | | |
|---|---|---|---|---|---|---|
| | Number of samples tested | Average breakdown voltage, volts | Standard deviation | Number of samples tested | Average breakdown voltage, volts | Standard deviation |
| 0 | 20 | 14.25 | 1.02 | 20 | 14.71 | 0.85 |
| 140 | 8 | 13.44 | 0.75 | 20 | 13.80 | 0.82 |
| 240 | 14 | 12.96 | 0.40 | 9 | 12.72 | 1.38 |

characteristics compared to switches used for the tests shown in Table II. Improvements in the type, as well as in the technique of application, of the protective plastic coating on the finished switches can probably be achieved.

In the shock tests, the switch successfully withstood accelerations of more than 7000 g, and could probably withstand even greater shocks. In radiation tests, a gamma dosage of $6 \times 10^4$R and a neutron dosage of $1.6 \times 10^{12}$ neutrons per cm$^2$ (fission spectrum) have had no effect on its breakdown properties.

## Theory of Switch Breakdown

No definite information is available on the nature of the low-resistance conducting path obtained after breakdown. Whitehead[26] suggests that a channel containing a number of ionized atoms or lattice points is left behind an avalanche breakdown in a dielectric solid. Aluminum ions may well be the current carriers in the broken-down switch.

Mere removal of the applied voltage does not restore the insulating layer after a breakdown pulse has established a current path across it. The dielectric breakdown occurring in these films is not reversible.

This fact is not surprising if it is remembered[27] that, in contrast to gases, solid insulators suffer destruction through the electrical breakdown current. Although it has been claimed[28] that this destructive breakdown is preceded by a preliminary stage of incomplete breakdown which has been reported[29] to be reversible at least for some insulators, it is generally assumed that physical damage to the lattice structure results from the electron avalanches which cause true breakdown of solid dielectrics in an electrostatic field. According to von Hippel's theory,[30] to which Zener,[31] Froehlich,[32] Seitz[33] and others have contributed, these electron avalanches are the cumulative effect of successive impact ionization. Both electrons and positive ions are produced through ionization, but only the electrons gain sufficient acceleration by the field to overcome the retardation caused by the interaction with the vibrational waves of the lattice and, consequently, to form avalanches.

In contrast to the mechanism that occurs in solid insulators, the reversible avalanche breakdown observed, for instance, in silicon diodes, has been explained[34] by carrier injection and consequent ionization of both electrons and holes, both of which have about equal ionization rates in extrinsic semiconductor junctions. As a result, reversible avalanches and nondestructive breakdown occur in silicon *p-n* junctions at much lower field strengths than those required for the intrinsic electric breakdown in pure aluminum oxide.

The reopening of a broken-down switch by the passage of a relatively strong current can hardly be explained by assuming reversibility of the breakdown process. It is more likely that the heat produced by this current caused thermal destruction of the damaged area, by a mechanism similar to that suggested by Wagner.[35] By eliminating the weak spots in the insulating film, the over-all dielectric strength of the oxide layer was thus essentially restored, while its area was reduced only insignificantly.

Also, the lower breakdown strength of the switch under a sustained potential, compared with that of a dc pulse, may be due to heating effects. Keller[36] has reported similar results in his measurements of the intrinsic electric strength of glass.

## Applications of the Switch

The switch has many advantages over the present glass thyratron. It is rugged, contains no moving parts, requires no "A" supply, is inexpensive, and is small, not more than $\frac{1}{2}$ inch in diameter and $\frac{1}{16}$ inch in thickness. Thus, the use of such a device would reduce over-all volume as well as power requirements.

Other characteristics of the switch may be an advantage or a disadvantage. First, the switch is a two-terminal device. Although it has no grid to give isolation between input and output circuits, undesirable effects of this construction can be minimized, as explained in Part C below. Second, the switch is primarily at one-time-use device. Third, the capacitance of the switch limits its use in certain applications. For example, a switch capacitance of 0.002 $\mu$f, when charged through a large resistance, would limit the use of the switch as far as short-duration pulses are concerned.

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[26] S. Whitehead, "Dielectric Breakdown of Solids," Clarendon Press, Oxford, Eng.; 1951.

[27] W. Franz, "Theory of the purely electric breakdown of solid insulators," *Ergeb. exakt. Naturw.*, vol. 27, p. 1; 1953.

[28] B. M. Vul, *J. Tech. Phys., USSR*, vol. 2, p. 1; January, 1932. Quoted by B. A. Chuenkov, "The modern state of the theory of electric breakdown of solid dielectrics," *Progr. Phys. Sci., USSR*, vol. 54, p. 186, October, 1954, Translation No. 2755 of the AEC.

[29] Yu. M. Volokobinski, "The influence of electric fields on the properties of thin dielectric and semiconducting films," *Proc. Acad. Sci. USSR*, Phys. Section, vol. 113, p. 1023; no. 5, 1957. Translation in *Soviet Physics*, "Doklady," vol. 2, p. 173; March/April, 1957.

[30] A. von Hippel, "Electric breakdown in solids and liquid insulators," *J. Appl. Phys.*, vol. 8, p. 815; December, 1937; and "Electric breakdown of solid dielectrics," *Trans. Faraday Soc.*, vol. 42A "Dielectrics," p. 78; 1946.

[31] C. Zener, "A theory of the electrical breakdown of solid dielectrics," *Proc. Royal Soc., London*, ser. A, vol. 145, p. 523; July 2, 1934.

[32] H. Froehlich, "On the theory of dielectric breakdown in solids," *Proc. Royal Soc., London*, ser. A, vol. 188, p. 521; February 25, 1947.

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[34] K. G. McKay, "Avalanche breakdown in silicon," *Phys. Rev.*, vol. 94, p. 877; May 15, 1954.

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[36] K. J. Keller, "The measurement of the intrinsic electric strength of glass," *Physica*, vol. 14, p. 475; September, 1948; and "Breakdown and electric conductivity of glass," *Physica*, vol. 17, p. 511; May, 1951.

These limitations can be overcome in certain cases by proper circuit applications and biasing techniques. In the work that follows, the switches that were used had an electrode diameter of $\frac{1}{4}$ inch and a breakdown voltage of approximately 14.5 volts.

### A. Time Delay

Fig. 5 shows the use of a voltage-sensitive switch in a time-delay circuit. The value of the charging capacitor is chosen such that the parallel capacitance of the switch can be neglected; hence, the charging resistor, the charging capacitor, and the actual breakdown voltage will affect the delay. For a more accurate delay, the capacitance of the switch would have to be known. When voltage is applied to the input terminals, the charging capacitor will charge in the normal manner through the charging resistor, and this voltage will appear across the voltage-sensitive switch until the voltage reaches the critical voltage of the switch, at which time the switch breaks down. At breakdown, the energy stored on the capacitor and on the switch, are passed through the closed switch into the load. In this arrangement the load would have to function with these combined energies. At low voltages, this energy can be very small but in stacked-switch circuits, the energy can be increased with higher terminal voltage.

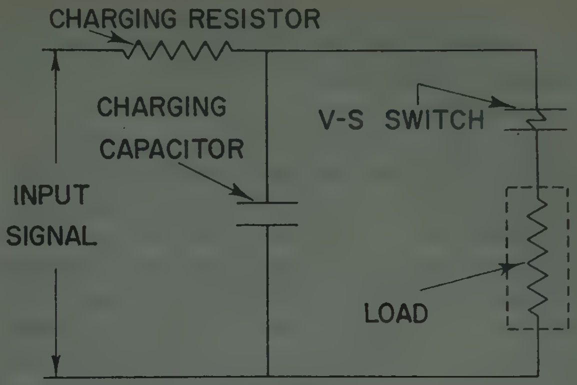

Fig. 5—Use of a voltage-sensitive switch in a time-delay circuit.

### B. Series Arrangement

In Fig. 6 the switch is used in a series circuit. The size of the signal voltage required to close the switch can be adjusted by means of the bias potential which, in turn, is limited by the minimum breakdown voltage of the switch. The signal voltage plus the biasing voltage should be large enough to exceed the critical breakdown voltage of the switch and cause breakdown. At breakdown, the switch impedance drops to 1 ohm or less, placing the load directly across the bias voltage through the transformer.

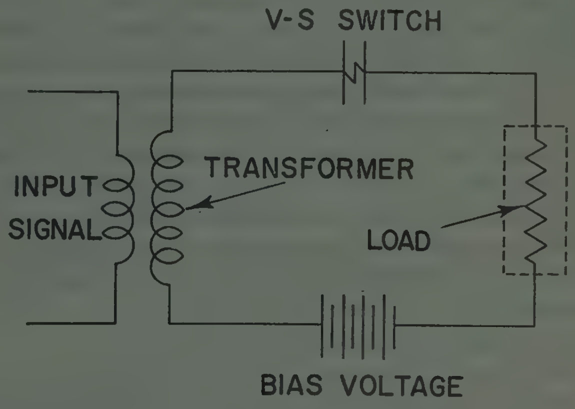

Fig. 6—Use of a voltage-sensitive switch in a series arrangement.

### C. Stacked Arrangements for Use at Voltages Higher than Critical

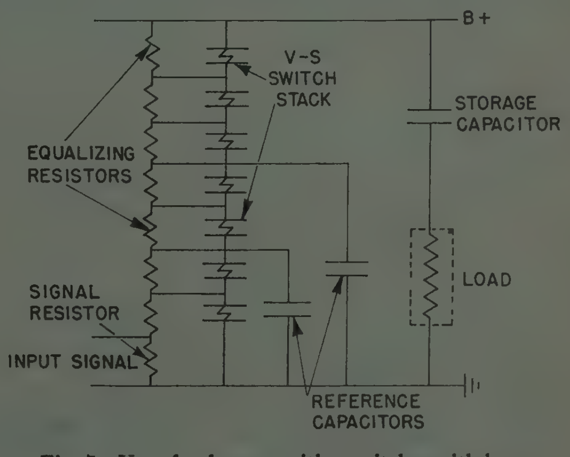

Fig. 7—Use of voltage-sensitive switches with large biasing voltages, signal injected in parallel.

Fig. 7 shows how the voltage-sensitive switches may be stacked as the terminal voltage is increased. This increase in terminal voltage also increases the energy available in the storage capacitor. This circuit shows seven switches; hence, terminal voltage must be less than seven times the critical voltage of one switch. Equalizing resistors are placed across the switches to assure equal voltage drop on each unit; an input resistor is placed in series with the lowest equalizing resistor to ground.

This input resistor serves several purposes. First, it serves as an impedance matching device for the signal generating source. Since it is usually of small nominal value compared to that of the equalizing resistors, its value can be chosen to match the output of the generator. The input resistor is essentially in parallel with the equalizing resistors through the load circuit to ground. The series combination of the equalizer resistors is usually large enough to prevent loading of the equivalent parallel resistance; so matching is not disturbed to any great extent.

Second, when matching generator impedance is not important, the input resistor serves as a reference resistor in order to maintain constant biasing voltage. This is particularly important when only two or three switches are used in the stack. Since it is purposefully made small compared to the equalizing resistors, practically none of the biasing voltage appears across it. If the generator's dc resistance is high, then the effect of the signal resistor in parallel with the generator resistance is to make the total resistance at the input terminals smaller than the signal resistor. Since the equalizing resistors are large in comparison, the dc bias is not changed. Conversely, if the generator's dc resistance is small, the resistance at the input terminals is again small and biasing is not affected. If the signal were injected without the signal resistor from a generator with a high dc resistance, it would be possible for the biasing voltage to shift and cause more than critical voltage to appear across a switch, hence breakdown without a signal would occur. This shift in biasing voltage would be determined by the relative magnitudes of the equalizing resistors and the dc resistance of the generator.

The reference capacitors are used for a large stack and are not necessary for a two or three-switch stack. Without these capacitors in a large stack, the voltage redistribution within the equalizing resistors may cause a shift within the normal spread of critical voltages in a given lot. The use of a reference capacitor holds the voltages well above this point and assures breakdown.

The input signal is injected across the signal resistor and is added in series with the biasing voltage across the lower switch to cause breakdown. As breakdown continues, the equalizing resistors are removed from the stack by the closed switches and, due to voltage redistribution, all the remaining switches break down.

Without the input resistor, the requirements of the generator would be that it not affect biasing voltages and that it have an output voltage greater than the critical voltage of the switch.

This circuit is limited in its application due to the charge time involved in charging the lower switch. However, this time is somewhat at the discretion of the designer.

## ACKNOWLEDGMENT

The authors wish to thank the following members of the Diamond Ordnance Fuze Laboratories for their contribution to this work: R. W. Tucker, for helpful discussions; L. H. Bullis, for the vapor deposition of films of aluminum; J. Samuel, C. S. Porter and H. W. Gilliand, for the design and construction of a test circuit; W. V. Behrens, for breakdown measurements under short pulses, and S. Graves and Mrs. L. N. Daniel for their assistance in various experiments. They also thank Mrs. M. E. Gale of the Atomic Energy Research Establishment, Harwell, England, for bringing to their attention the research carried out at those laboratories.

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# Methods of Measurement of the Parameters of Piezoelectric Vibrators*

E. A. GERBER†, FELLOW, IRE, AND L. F. KOERNER‡, MEMBER, IRE

*Summary*—The "IRE Standards on Piezoelectric Crystals—The Piezoelectric Vibrator" specifies nomenclature and methods of measurement of the various quantities associated with piezoelectric vibrators. This paper gives in detail the theoretical considerations of these measurements, which are based on the frequency of maximum transmission through a simple pi resistance network which includes the vibrator in the series arm. The motional resonance frequency of the vibrator and the value of the motional resistance by the substitution of a resistor in place of the vibrator may be obtained from the frequency measurement. The theoretical considerations take into account stray capacitances and other impedances, and show how the somewhat involved formulas may be simplified with the average run of presently available vibrators. By the aid of capacitance-bridge measurements and frequency measurements of the vibrator with series impedances, all of the elements of its equivalent electrical circuit may be determined.

Charts based on the formulas are included. They relate the measured to the fundamental values of the vibrator elements with any desired degree of precision. It is shown that when using typical quartz vibrators, the measurement of the frequency at maximum transmission will not differ from its value at motional resonance by more than a few parts in a million. Resistance substitution measurements have been found to compare within about two per cent.

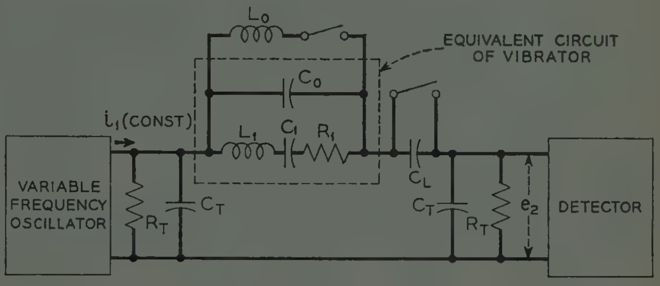
In addition to the generally available resistance and capacitance bridges, transmission network measurements require a stable RF generator or oscillator, the transmission network, and a sensitive detector. The transmission network consists simply of four resistors and some form of a socket or terminals to connect to the vibrator. A mechanical design which reduces stray capacitances and inductances to a minimum is given. The effect of detector sensitivity on measurement accuracy is described and where low-current, high-accuracy measurements are required, high-gain moderately frequency selective detectors are suggested.

The work is summarized in Tables I and II which indicate the relationships between measured and fundamental vibrator parameters, and should give the engineer the necessary background for piezoelectric vibrator measurements.

## I. INTRODUCTION

THIS method of measuring the parameters of piezoelectric vibrators was published originally in 1951[1] and has since become an IRE Standard.[2] It consists of determining the frequency and impedance at maximum transmission (maximum transfer impedance) of a $\pi$ network in which the vibrator under test is in the series branch. The frequency $f_{mT}$ at maximum transmission (maximum output voltage) is measured with and without a capacitance $C_L$ in series with the vibrator. From these measurements, the motional resonance frequency $f_s$, the motional capacitance $C_1$, and the motional resistance $R_1$ of the vibrator can be determined. The latter is obtained by substituting resistors $R_{ST}$ in place of the vibrator to obtain equivalent output voltage.

Fig. 1 illustrates the principle of the method. The measuring circuit consists of a power source in the form of a variable frequency oscillator, the transmission network, and a detector. The piezoelectric vibrator is represented here by its equivalent circuit. The capacitances $C_T$ shunting the terminating resistances $R_T$ represent an unavoidable contribution from the circuit which cannot be neglected at high frequencies. The inductance $L_0$, connected across the vibrator, serves to resonate the shunt capacitance $C_0$ of the vibrator. As explained later, this added component will improve the accuracy of measurement.



$$\omega_s = (L_1C_1)^{-1/2}; \quad Q = \frac{\omega_s L_1}{R_1}; \quad r = \frac{C_0}{C_1}; \quad M = \frac{Q}{r} = \frac{1}{\omega_s C_0 R_1} = \frac{X_0}{R_1}$$

$$M_T = \frac{1}{\omega_s C_T R_T} = \frac{X_T}{R_T}; \quad x = \frac{\omega^2}{\omega_s^2} - 1; \quad b = 1 - \frac{1}{L_0 C_0 \omega_s^2}$$

Fig. 1—Schematic of transmission circuit method.

## II. THEORY

Since the frequency at maximum transmission $f_{mT}$ and the maximum transfer impedance $(e_2/i_1)_{\max}$ or minimum transfer admittance $(i_1/e_2)_{\min}$ are measured and the fundamental vibrator parameters $f_s$, $R_1$, and $C_1$ are desired, relations between these values must be derived. These relations must cover as large a variety of vibrator and circuit parameters as possible.

In the following analysis, only two simplifying assumptions have been made:

1) The input current $i_1$ is constant.
2) The impedance (or admittance) of the vibrator can be represented by a circle diagram. This assumption is valid if the square of the quality factor $Q$ is large in comparison to the capacitance ratio $r$ or $(Q^2/r) \gg 1$. Fig. 2 gives a derivation of this condition and Table I gives data for $Q$, $r$, and $Q^2/r$ for various types of vibrators indicating that the above assumption is valid for all practical cases.

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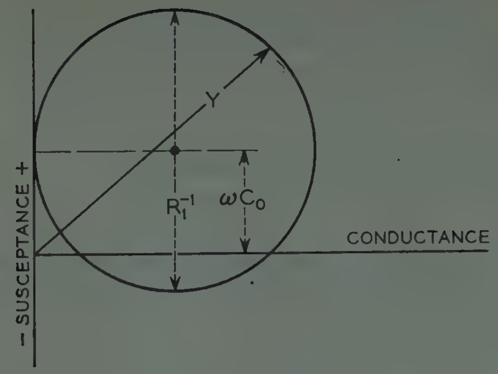
† U. S. Army Signal Res. and Dev. Lab., Fort Monmouth, N. J.
‡ Bell Telephone Labs., Inc., Whippany, N. J.

[1] L. F. Koerner, "Progress in development of test oscillators for crystal units," PROC. IRE, vol. 39, pp. 16–26; January, 1951.

[2] "IRE Standards on piezoelectric crystals—the piezoelectric vibrator: definitions and methods of measurement, 1957," PROC. IRE, vol. 45, pp. 353–358; March, 1957.



Circle representation for admittance is valid if diameter $R_1^{-1}$ is large in comparison with the change of $\omega C_0$ in the resonance rang or if

$$\frac{1}{R_1} \gg \Delta\omega C_0$$

Since $\Delta\omega = \omega_s/Q$ for 45° detuning of $L_1$, $C_1$, $R_1$ branch:

$$\frac{1}{R_1} \gg \frac{\omega_s}{Q} C_0$$

or

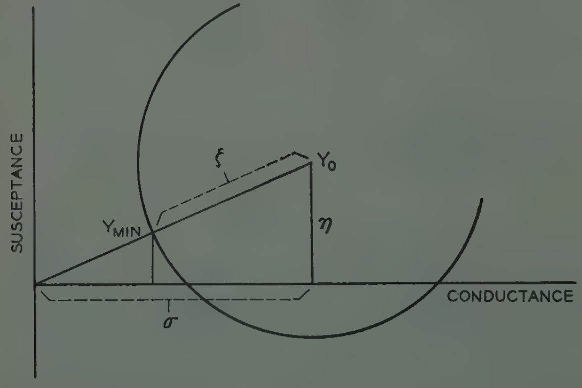
$$\frac{Q^2}{r} \gg 1$$

Fig. 2—Admittance diagram of a piezoelectric vibrator.

TABLE I

MINIMUM VALUES FOR THE RATIO $Q^2/r$ TO BE EXPECTED FOR VARIOUS TYPES OF PIEZOELECTRIC VIBRATORS

| Type of Piezoelectric Vibrator | $Q = Mr$ | $r$ | $(Q^2/r)_{\min}$ |
|---|---|---|---|
| Piezoelectric Ceramics | 90–500 | 5–40 | 200 |
| Water Soluble Piezo-electric Crystals | 200–50,000 | 3–500 | 80 |
| Quartz | $10^4$–$10^7$ | 100–50,000 | 2000 |



$$Y_{\min} = [1 - \rho(\sigma^2 + \eta^2)^{1/2}][\sigma + j\eta]$$
$$|Y_{\min}| = (\sigma^2 + \eta^2)^{1/2} - \rho$$

Fig. 3—Coordinates of circle for minimum transfer admittance.

As stated by Harrison[3] and Gerber,[4] conformal representation is considered a very convenient tool for any circuit analysis involving crystals. The basis for this analysis is the equation of the linear fractional transformation,

$$Y = \frac{\alpha + \beta Z}{\gamma + \delta Z}. \tag{1}$$

Eq. (1) can represent any impedance or admittance whose frequency of operation is controlled by a crystal. The terms $\alpha$, $\beta$, $\gamma$, and $\delta$ are complex constants and $Z$ represents a complex variable which is a function of frequency.

### A. Equation for Motional Resistance

Calculating the transfer admittance $Y = i_1/e_2$ of the network of Fig. 1 and comparing it with (1) yields for $\alpha$, $\beta$, $\gamma$, $\delta$, and $Z$:

$$\begin{aligned}
\alpha &= \frac{R_1}{R_T}\left(1 - \frac{1}{M_T^2}\right) + 2\left(1 - \frac{b}{MM_T}\right) \\
&\qquad + 2j\left(\frac{b}{M} + \frac{R_1}{R_TM_T} + \frac{1}{M_T}\right), \\
\beta &= M\left[\frac{R_1}{R_T}\left(1 - \frac{1}{M_T^2}\right) - \frac{2b}{MM_T} + 2j\left(\frac{b}{M} + \frac{R_1}{R_TM_T}\right)\right], \\
\gamma &= \left(1 + j\frac{b}{M}\right)R_T, \\
\delta &= jbR_T, \\
Z &= jrx.
\end{aligned} \tag{2}$$

The symbols used in (2) are explained in Fig. 1. $Y$, the admittance variable, is a circle in the $Y$ plane, and $Z$, the frequency variable, is a line coincident with the imaginary axis in the $Z$ plane. $Y_{\min}$ is the minimum admittance to be sought (see Fig. 3). Its absolute value amounts to

$$\left|\left(\frac{i_1}{e_2}\right)_{\min}\right| = |Y_{\min}| = (\sigma^2 + \eta^2)^{1/2} - \rho, \tag{3}$$

where $\sigma$ and $\eta$ are the coordinates of the center of the circle, equal to

$$Y_0 = \sigma + j\eta = \frac{\alpha\delta + \beta\bar{\gamma}}{\gamma\bar{\delta} + \bar{\gamma}\delta}, \tag{4}$$

and $\rho$ is the radius of the circle expressed by

$$\rho = \left|\frac{\beta}{\delta}\right| \cdot \left|\frac{\dfrac{\alpha}{\beta} - \dfrac{\gamma}{\delta}}{\dfrac{\gamma}{\delta} + \dfrac{\bar{\gamma}}{\bar{\delta}}}\right|. \tag{5}$$

Inserting (4) and (5) into (3) and using (2), for $Y_{\min}$ we obtain:

$$\begin{aligned}
|Y_{\min}| &= \frac{M^2R_1}{2R_T^2b^2}\left(1 + \frac{1}{M_T^2}\right) \\
&\cdot\left[\left\{B^2 + \frac{4b^2}{M^2}C + \frac{1}{M_T^2}\left(1 + \frac{4b^2}{M^2}\right)\right\}^{1/2} - 1\right],
\end{aligned} \tag{6}$$

where

$$B = 1 + \frac{4b^2R_T}{M^2R_1}, \tag{6a}$$

and

$$C = 1 + \frac{4bR_T}{MM_TR_1}. \tag{6b}$$

If the vibrator is replaced by a substitution resistor $R_{ST}$ resulting in the same output voltage $e_2$, for $Y$ we have:

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[3] C. W. Harrison, "The measurement of the performance index of quartz plates," *Bell Sys. Tech. J.*, vol. 24, pp. 217–252; April, 1945.

[4] E. A. Gerber, "Quartz-crystal measurement at 10 to 100 megacycles," PROC. IRE, vol. 40, pp. 36–40; January, 1952.

$$|Y_{R_{ST}}| = \frac{1}{R_T}\left\{\left[2+\frac{R_{ST}}{R_T}\left(1+\frac{1}{M_T^2}\right)\right]^2+\frac{4}{M_T^2}\right\}^{1/2}. \tag{7}$$

Equating (6) and (7) yields finally for the motional resistance $R_1$ to be sought

$$R_1 = R_T \frac{2 - A}{\dfrac{R_T^2}{X_0^2}\dfrac{b^2A^2}{1+R_T^2/X_T^2} - 4b\dfrac{R_T}{X_0}\left(\dfrac{R_T}{X_0}b+\dfrac{R_T}{X_T}\right)-\left(1+\dfrac{R_T^2}{X_T^2}\right)}, \tag{8}$$

where

$$A = \left\{\left[2+\frac{R_{ST}}{R_T}\left(1+\frac{R_T^2}{X_T^2}\right)\right]^2+4\frac{R_T^2}{X_T^2}\right\}^{1/2}.$$

This equation is rather complicated for practical use. It can be simplified considerably if the combination $L_0C_0$ is tuned to $\omega_s^2=1/C_1L_1$, in other words, if $b=0$; or if $C_T=0$; or $R_T=\infty$; or

$$\frac{4}{M_T^2} = 4\frac{X_T^2}{R_T^2} \ll 1.$$

(For the meaning of the symbols, refer to Fig. 1.) Table II depicts a compilation of the expressions for $R_1$ valid for the various simplifying assumptions.

### B. Equation for Motional Resonance Frequency

For the purpose of finding an exact expression for the frequency at minimum transfer admittance, we calculate

$$x = \frac{\omega^2_{mT}}{\omega_s^2} - 1,$$

TABLE II

RELATIONSHIP BETWEEN MEASURED AND FUNDAMENTAL VALUES

| | $R_1=$ | | $x=\dfrac{\omega^2_{mT}}{\omega_S^2}-1=$ | |
|---|---|---|---|---|
| Complete Solution | $\dfrac{R_T(2-\sqrt{\ })}{\dfrac{C_0^2}{C_T^2}\dfrac{b^2\sqrt{\ }^2}{1+M_T^2}-\dfrac{4b}{M_T^2}\dfrac{C_0}{C_T}\left(b\dfrac{C_0}{C_T}+1\right)-\left(1+\dfrac{1}{M_T^2}\right)}$<br>$\sqrt{\ }=\sqrt{\left[2+\dfrac{R_{ST}}{R_T}\left(1+\dfrac{1}{M_T^2}\right)\right]^2+\dfrac{4}{M_T^2}}$ | (8) | $\dfrac{1}{r_b}+\dfrac{\dfrac{b}{rM^2}\left(1+C+\dfrac{2}{M_T^2}\right)}{B-1+\left(1+\dfrac{1}{M_T^2}\right)\left(1-\sqrt{\dfrac{1}{1+M_T^2}\left[B^2+\dfrac{4b^2}{M^2}C+\dfrac{1}{M_T^2}\left(1+\dfrac{4b^2}{M^2}\right)\right]}\right)}$<br>$B=1+\dfrac{4b^2R_T}{M^2R_1};\qquad C=1+\dfrac{4bR_T}{MM_TR_1}$ | (10) |
| $b=0$ | $\dfrac{R_T\left(\sqrt{\left[2+\dfrac{R_{ST}}{R_T}\left(1+\dfrac{1}{M_T^2}\right)\right]^2+\dfrac{4}{M_T^2}}-2\right]}{1+\dfrac{1}{M_T^2}}$ | (8a) | $\dfrac{2R_T}{rMM_TR_1\left(1+\dfrac{1}{M_T^2}\right)}$ | (10a) |
| $C_T=0$ | $\dfrac{R_{ST}}{1-\dfrac{R_{ST}^2}{X_0^2}b^2\left(4\dfrac{R_T}{R_{ST}}+1\right)}$ | (8b) | $\dfrac{1}{rb}+\dfrac{2b}{rM^2B\left(1-\sqrt{1+\dfrac{4b^2}{M^2B^2}}\right)}$, | (10b) |
| $R_T=\infty$ | $\dfrac{R_{ST}\sqrt{1+\left(\dfrac{2X_T}{R_{ST}}\right)^2}}{1+4b\dfrac{C_0}{C_T}-\dfrac{R_{ST}^2}{X_0^2}b^2}$ | (8c) | $\dfrac{1}{rb}+\dfrac{2b\left(2b\dfrac{C_0}{C_T}+1\right)}{rM^2\left(1-\sqrt{\dfrac{4b^2}{M^2}\left(1+2b\dfrac{C_0}{C_T}\right)^2+1}\right)}$ | (10c) |
| $\dfrac{4}{M_T^2}\ll 1$ | $\dfrac{R_{ST}}{1+\dfrac{4b}{M_T^2}\dfrac{C_0}{C_T}-\dfrac{b^2}{M_T^2}\left(\dfrac{R_{ST}C_0}{R_TC_T}\right)^2\left(1+4\dfrac{R_T}{R_{ST}}\right)}$ | (8d) | $\dfrac{2}{M^2r}\dfrac{C_TR_T^2}{C_0R_1^2}-\dfrac{4bR_T}{M^2R_1r}-\dfrac{b}{M^2r}$<br>is valid for $b^2/M^2\ll 1$ | (10d) |
| $b=0$;<br>$R_T=\infty$ | $R_{ST}\sqrt{1+\left(\dfrac{2X_T}{R_{ST}}\right)^2}$ | (8e) | $2\dfrac{C_1}{C_T}$ | (10e) |
| $b=0$;<br>$C_T=0$ | $R_{ST}$ | (8f) | $0$ | (10f) |

corresponding to this condition, by transforming the minimum admittance point $Y_{\min}$ into the $Z$ plane. From (1) we derive

$$Z = \frac{\alpha - \gamma Y_{\min}}{\delta Y_{\min} - \beta} = jxr. \tag{9}$$

$Y_{\min}$ is split into its real and imaginary parts according to Fig. 3 and inserted into (9). Using the values for $\sigma$, $\eta$, and $\rho$ from (4) and (5), the values of $\alpha$, $\beta$, $\gamma$, and $\delta$ from (2) and solving (9) in terms of $x$ yields:

$$x = \frac{1}{rb} + \frac{\dfrac{b}{rM^2}\left(1 + C + \dfrac{2}{M_T{}^2}\right)}{B - 1 + \left(1 + \dfrac{1}{M_T{}^2}\right)\left[1 - \left\{\dfrac{1}{1 + \dfrac{1}{M_T{}^2}}\left[B^2 + \dfrac{4b^2}{M^2}C + \dfrac{1}{M_T{}^2}\left(1 + \dfrac{4b^2}{M^2}\right)\right]\right\}^{1/2}\right]}, \tag{10}$$

wherein $B$ and $C$ are the values defined in (6a) and (6b).

Eq. (10) gives the exact deviation of the frequency at minimum transfer admittance $f_{mT}$ from the motional resonance frequency $f_s$ of the vibrator. The equation can be further simplified if the assumptions mentioned above are made (see Table II). Especially, the case where the terminating impedance is purely reactive ($R_T = \infty$) will be important for higher frequencies, since it is easier to realize a pure reactance than a pure resistance. In addition, the maximum for $e_2$ will be sharper because the $Q$ of the vibrator is not degraded by the series connection of the two resistances $R_T$.

## III. Circuit Details

### A. Variable Frequency Oscillator

The requirements for the variable frequency oscillator are constant output, high short-time frequency stability, and purity of waveform if a nonselective detector is used. The frequency stability should be greater than the desired accuracy of resonance frequency measurement, since frequency "jitter" will dull the peak of detector output. The constancy of the oscillator output should be such that there will be no noticeable detector output variation over the range of measurement frequency. However, for the measurement of quartz vibrators, the output of the oscillator need only be constant over a relatively narrow frequency band since the resonances are quite sharp.

Satisfactory oscillators include the crystal controlled crystal unit test sets operating at the desired frequency, frequency synthesizers, and lock-in oscillators[5] (which may be operated to ±1 PP $10^6$ or better from audio frequencies to over 100 mc).

Standard coaxial cable output impedances for the oscillator will generally be satisfactory. The power output of the oscillator should be sufficient to obtain desired currents through the vibrator under test.

### B. Detectors

Satisfactory detectors include vacuum tube voltmeters, diode rectifiers working into galvanometers for low-current, high-frequency work, and tuned radio receivers with output meters. The sensitivity of the detector may be defined as the ratio of the smallest detectable change in meter deflection to the total meter deflection.

The IRE Standards on the Piezoelectric Crystals[2] gives the deviation of $f_s$ from its true value; due to detector sensitivity $S$ alone as

$$x \approx \frac{\Delta f}{f_s} = 0.707\left(\frac{2R_T}{R_1} + 1\right)\frac{\sqrt{S}}{Q}. \tag{11}$$

It has been derived by using the method described in Section II and is valid if $4/M_T{}^2 \ll 1$ and $b^2/M^2 \ll 1$. Eq. (11) is conveniently evaluated after $R_1$ and $Q$ have been determined (see Sections IV-B and IV-C).

### C. Transmission Network

The transmission network is a relatively simple device (see Fig. 4) composed of four resistors, a vibrator socket if required, and appropriate connectors at the

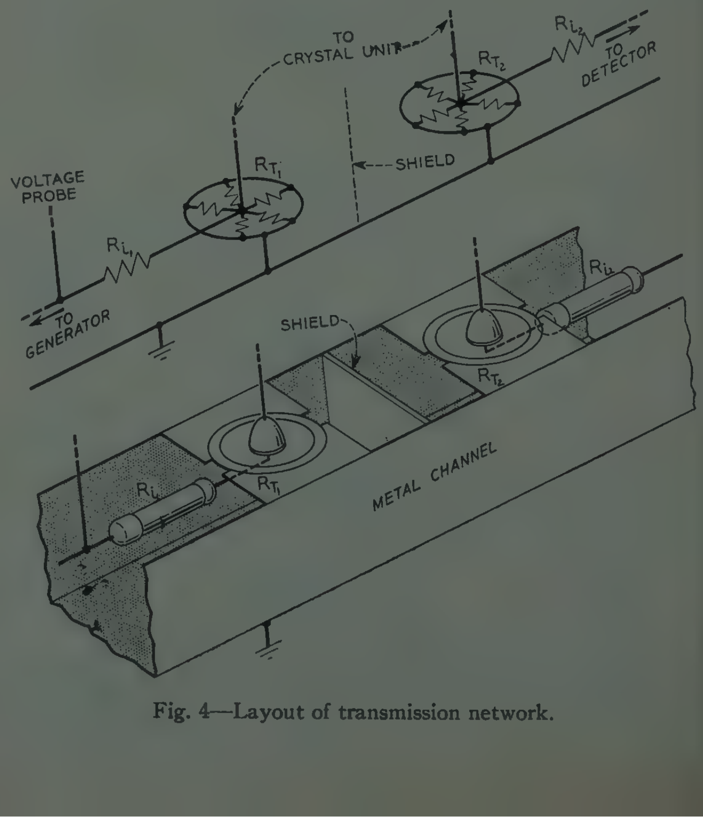

Fig. 4—Layout of transmission network.

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[5] L. F. Koerner, "A variable frequency oscillator stabilized to high precision," *Bell Labs. Rec.*, vol. 28, pp. 66–71; February, 1950.

input and output terminals. In the input and output portions of the network are isolating resistors $R_i$ made sufficiently large (usually $> 10\ R_T$) so that the magnitude and character of external oscillator or detector impedance may be neglected, and the input current $i_1$ can be assumed to be constant.

Since the high-frequency transmission networks impose most of the design problems, these networks will be minutely described. Fig. 4 shows the positioning of the components and Fig. 5 suggests details of the construction of such a network. The shunt resistors $R_T$ may be of the concentric disk type having the outer connecting rim grounded. The series resistors $R_i$ may be miniature $\frac{1}{8}$-watt high-frequency resistors. The probe is used to measure the input voltage to the network. To reduce errors of measurement, it is good practice to make the value of $R_T$ not more than $\frac{1}{2}$ and preferably less than 1/10 of the vibrator resistance. The lower the resistance of $R_T$, the less the effect of its shunt capacitances and the sharper the output resonance peak.

### D. *Resistance Standards*

Two methods of resistance measurement are common: one, where a curve of detector current vs resistance is obtained by measurements with fixed values of resistance, the other, where a small carbon type potentiometer is adjusted for the same detector current, and a direct current resistance measurement of the value of the potentiometer is made with a Wheatstone bridge. The use of the potentiometer has frequency limitations due to the presence of impedances at higher frequencies. Comparative measurement of small $\frac{1}{2}$-watt fixed resistors vs an Allen Bradley Type J potentiometer shows that the error will be negligible up to at least 5 mc. Adjustable resistors have been developed which have built-in networks to compensate for frequency variations.[6] Recent test oscillators utilize these resistors which are measured with ohmmeters incorporated in the oscillators.

## IV. MEASUREMENTS

Through experience we know that, except for vibrator frequencies in the higher radio frequencies (>50 mc), transmission networks may be designed and constructed so that the capacitance $C_T$ is effectively zero and lead inductances, especially between the crystal socket and resistors $R_T$, are not detrimental. Accordingly, (8b) and (10b) in Table II will apply. Two conditions of measurement will follow: with the combination of shunting coil and $C_0$ tuned close to $f_s$, in which case $b=0$; or without the coil, in which case $b=1$. In general, the desirability for use of the coil will appear only at the higher frequencies, where the value of $R_{ST}$ or $R_1$ approaches $X_0$. To know the value of $X_0$, the capacitance $C_0$ must be known.

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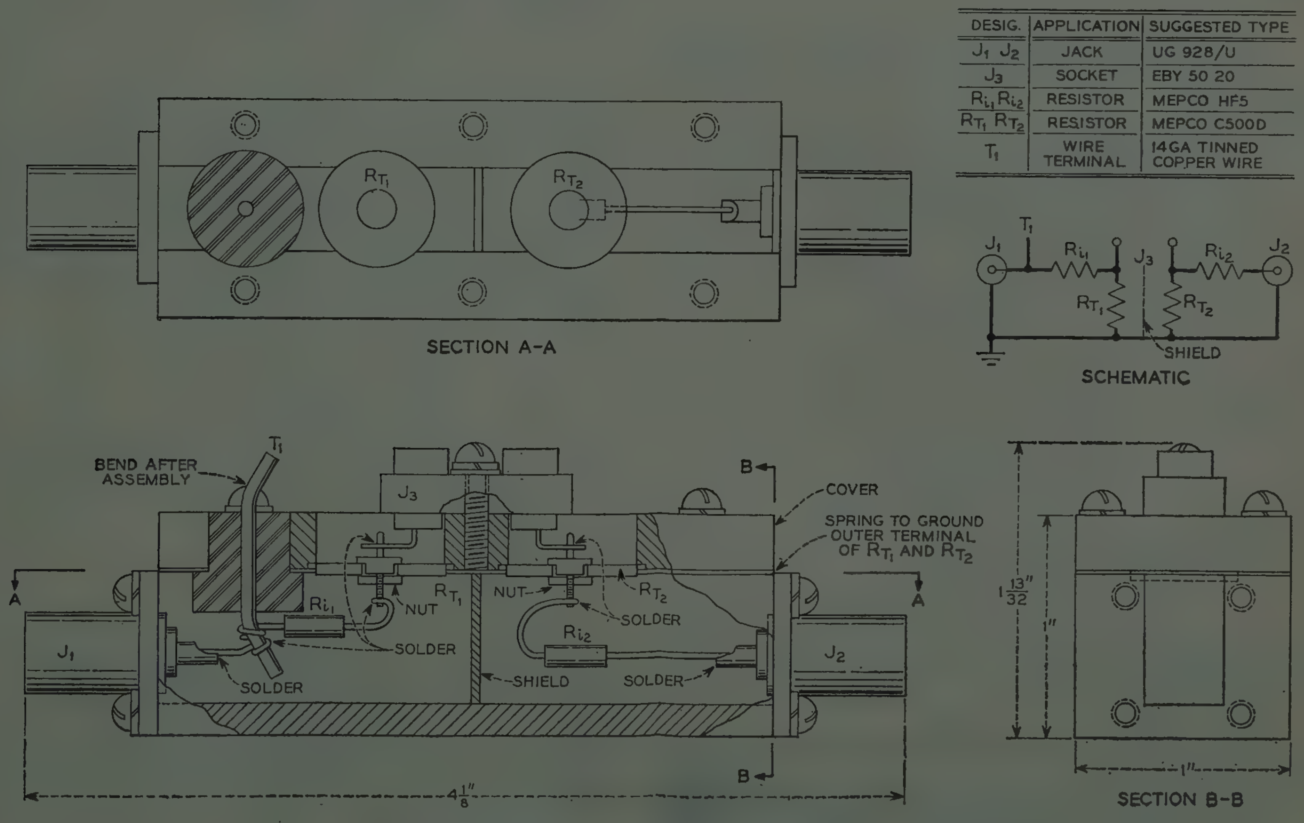
[6] "Investigation of Methods for Measuring the Equivalent Parameters of Quartz Crystals," Georgia Inst. Tech., Atlanta, Ga., final report on Contract No. DA-36-039-sc-56730, May 31, 1956.



| DESIG. | APPLICATION | SUGGESTED TYPE |
|---|---|---|
| $J_1$ $J_2$ | JACK | UG 928/U |
| $J_3$ | SOCKET | EBY 50 20 |
| $R_{i_1}$ $R_{i_2}$ | RESISTOR | MEPCO HF5 |
| $R_{T_1}$ $R_{T_2}$ | RESISTOR | MEPCO C500D |
| $T_1$ | WIRE TERMINAL | 14GA TINNED COPPER WIRE |

Fig. 5—Details of construction of transmission network.

### *A. Measurement of Shunt Capacitance $C_0$*

The shunt capacitance $C_0$ of the equivalent vibrator circuit may be measured with available capacitance bridges. With piezoelectric vibrators having a high capacitance ratio, for example quartz crystals, the measurement may be made at any convenient frequency removed from any resonances. In the case of a small capacitance ratio ($r<50$), as with certain piezoelectric ceramics, the capacitance may need to be measured at more specific frequencies.[7,8]

### *B. Measurement of Motional Resistance $R_1$*

A preliminary measurement of resistance will determine the desirability of using a shunting coil. This measurement is made without the coil by adjusting the frequency of the oscillator for maximum transmission and then determining the value of $R_{ST}$ by substituting a variable resistor in place of the vibrator. The next step is to find the value of

$$\left(\frac{R_{ST}}{X_0}\right)^2\cdot\left(\frac{R_T}{R_{ST}}+1\right)$$

from (8b) of Table II. The value of this expression times 100 will be the percentage error in resistance measurement, and if it is greater than the desired accuracy of measurement, it may be desirable to check the measurement with the shunting inductor, in which case the error in measurement, according to (8f) of Table II, will be zero.

### *C. Measurement of Motional Capacitance $C_1$ and Inductance $L_1$*

The procedure for the motional capacitance measurement consists of determining the frequency of maximum transmission with one or more load capacitances $C_L$ successively connected in series with the vibrator. If two capacitors $C_{L1}$ and $C_{L2}$ are used, $C_1$ follows from

$$C_1=\frac{2\Delta C_L}{f_s}\cdot\frac{\Delta f_1\Delta f_2}{\Delta f},\tag{12}$$

where

$$\begin{aligned}\Delta C_L &= C_{L2}-C_{L1},\\ \Delta f &= f_{sL1}-f_{sL2},\\ \Delta f_1 &= f_{sL1}-f_s,\\ \Delta f_2 &= f_{sL2}-f_s,\end{aligned}$$

and $f_{sL1}$ and $f_{sL2}$ are the motional resonance frequencies of the combination of vibrator plus $C_{L1}$ and vibrator plus $C_{L2}$, respectively. The values of the series capacitors $C_{L1}$ and $C_{L2}$ should be chosen so that the difference frequencies $\Delta f$, $\Delta f_1$, and $\Delta f_2$ are as large as possible. It will be noted that (12) contains the motional resonance frequencies, whereas the frequencies at maximum transmission are measured. The difference between these two groups of frequencies, however, is smaller than 1 per cent for $(Q^2/r)\geqq 80$. This may be readily found from (10d) of Table II, by setting $C_T=0$ and $b=1$. The accuracy of $\Delta C_L$ in (12) depends upon accuracy of measurement of $C_{L1}$ and $C_{L2}$ with the capacitance bridge. Since this accuracy is in most cases of the order of 1 per cent, the difference between the motional resonance frequencies and the frequencies at maximum transmission can be neglected in almost every case. Should higher accuracies be desired, the measured frequencies at maximum transmission can be converted into the motional resonance frequencies entering (12) by using (10)–(10f) in Table II, according to the specific operating conditions. It must be remembered in all these cases that the parameters $R_1$, $C_1$, $C_0$, $M$, $r$, and $Q$ in the above equations pertain now to the combination of vibrator plus $C_L$. They can be obtained from the vibrator parameters alone by the following relations, $u$ being equal to $(C_L+C_0)/C_L$:

$$\begin{aligned}R_{1L} &= R_1\cdot u^2,\\ C_{1L} &\approx C_1/u^2,\\ C_{0L} &= C_0/u,\\ M_L &= M/u,\\ r_L &= r\cdot u,\\ Q_L &= Q.\end{aligned}\tag{13}$$

With a given accuracy of frequency measurement, the error in the measurement of $C_1$ increases with higher capacitance ratios since the frequency change from resonance for added capacitance is inversely proportional to $r$. Care should be taken that the current through the crystal remains constant for different values of $C_L$.

The inductance $L_1$ may be calculated from

$$L_1=\frac{1}{4\pi^2 f_s^2 C_1}\cdot\tag{14}$$

Essentially, its accuracy of measurement is the accuracy of the measurement of $C_1$. The $Q$ of the vibrator is

$$Q=\frac{2\pi f_s L_1}{R_1}\cdot\tag{15}$$

### *D. Measurement of Motional Resonance Frequency $f_s$*

Assuming again that the transmission network is so designed that $C_T$ is zero, (10b) on Table II may be employed to obtain $f_s$ from the frequency at maximum transmission, $f_{mT}$. If no shunting inductance is used ($b=1$), (10b) becomes

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[7] E. A. Gerber, "A review of methods for measuring the constants of piezoelectric vibrators," PROC. IRE, vol. 41, pp. 1103–1112; September, 1953.

[8] R. Bechmann, "Contour modes of plates excited piezoelectrically and determination of elastic and piezoelectric coefficients," 1954 IRE CONVENTION RECORD, pt. 6, pp. 77–85.

$$\frac{\omega_{mT}^2}{\omega_s^2} - 1 = \frac{1}{r}\left\{1 + \frac{2}{M^2\left(1+\frac{4R_T}{M^2R_1}\right)\left[1 - \sqrt{1 + \frac{4}{M^2\left(1+\frac{4R_T}{M^2R_1}\right)^2}}\right]}\right\} \tag{16}$$

---

and, if $M^2 \gg 1$, from (10d)

$$\frac{\omega_{mT}^2}{\omega_s^2} - 1 = -\frac{1}{M^2 r}\left(\frac{4R_T}{R_1} + 1\right) = -\frac{r}{Q^2}\left(\frac{4R_T}{R_1} + 1\right).$$

Since the right-hand side of this equation is usually much smaller than unity, it can be written as

$$\frac{\Delta f}{f_s} = -\frac{r}{2Q^2}\left(\frac{4R_T}{R_1} + 1\right), \tag{17}$$

$$\frac{\Delta f}{f_s} \text{ being equal to } \frac{\omega_{mT} - \omega_s}{\omega_s}.$$

Previous measurements have given the values of $R_1$, $C_1$ and $C_0$. Thus the values of $Q$, $M$, and $r$ can be inserted into (16) or (17) to produce an exact value for $f_s$. Note that if a shunting inductor is used and the combination $L_0C_0$ is tuned close to $f_s$ ($b=0$), then $\Delta f$ becomes zero, according to (10f) in Table II. It must be decided in every case whether it is more convenient to use the shunting coil giving $R_1 = R_{ST}$ and $f_s = f_{mT}$, or to apply the corrections given in Table II and explained in Sections IV-B through IV-D. If the parallel loss resistance of the combination $L_0C_0$ is not large compared to the expected $R_1$, the use of the shunting coil will introduce errors.

## V. Numerical Examples

Eqs. (11), (8b) in Table II, and (17) which give values for the frequency error due to $S$, the resistance error, and the frequency error due to vibrator and network parameters, are plotted in graphical form in Figs. 6–8. It is assumed in all three cases that $2(R_T/R_1) \ll 1$ (Fig. 6), $4(R_T/R_{ST}) \ll 1$ (Fig. 7), and $4(R_T/R_1) \ll 1$ (Fig. 8). If these relations do not hold true, the ordinate values of the graphs can easily be modified.

The necessary corrections for some types of vibrators are shown in the graphs. These vibrators are listed in Fig. 6. A detector sensitivity of 0.1 per cent was assumed for these vibrations. Note in Fig. 7 that with the given examples, 2 per cent accuracy in the resistance measurement can be obtained without the use of shunting coils. Fig. 8 reveals that excluding the barium titanate ceramic example, frequency deviations of less than one part in a million are quite common. Again, no shunting coil was utilized in these measurements.

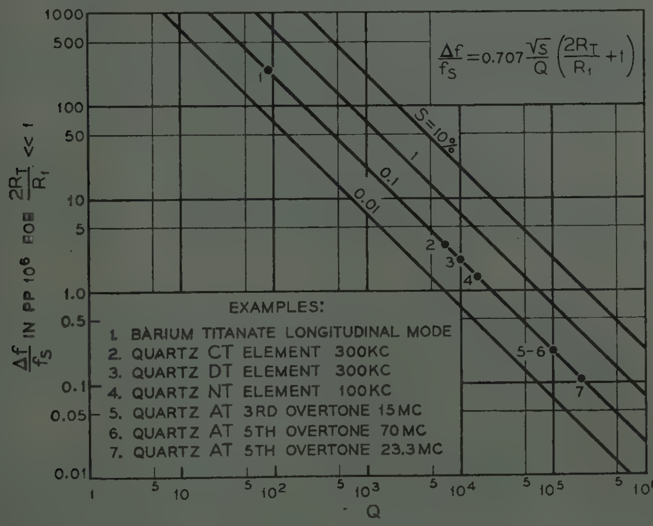

Fig. 6—Frequency error $\Delta f/f_s$ due to detector sensitivity $S$.

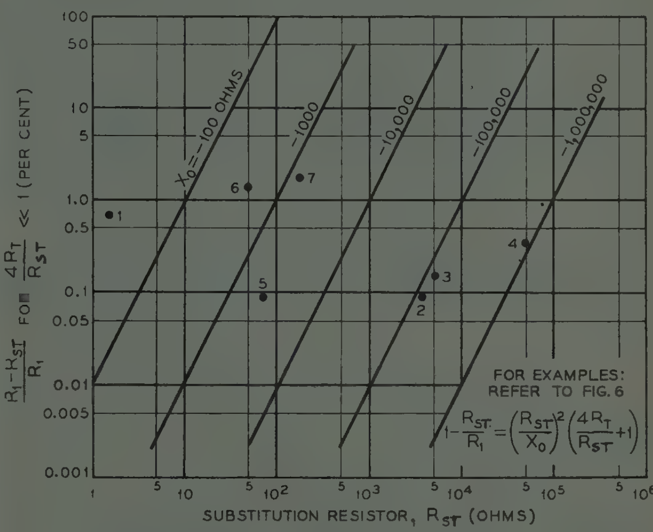

Fig. 7—Resistance error.

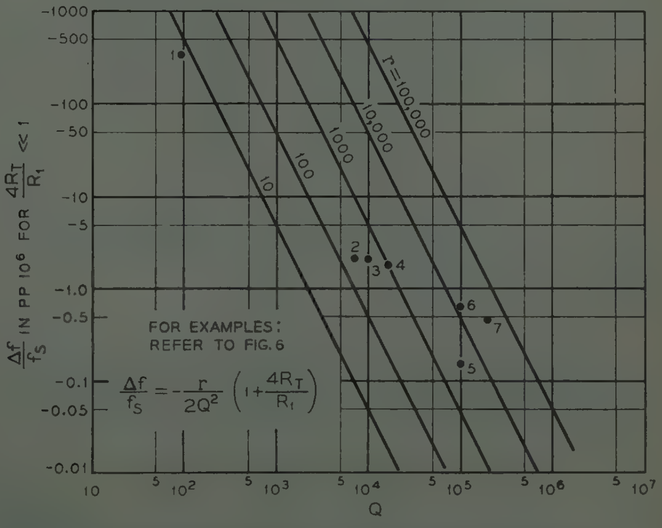

Fig. 8—Frequency error $\Delta f/f_s$ due to vibrator and circuit parameters.

# Harmonic Generation with Ideal Rectifiers*

CHESTER H. PAGE†, FELLOW, IRE

***Summary***—**It is shown that the $n$th harmonic cannot be generated with an efficiency exceeding $1/n^2$. Of the power converted to dc and harmonics, at least 75 per cent is dc dissipation, and this cannot be reduced by an arrangement of selective circuits.**

## INTRODUCTION

EVERY so often, circuits are proposed for generating harmonics with high efficiency, using ideal rectifiers. The accompanying arguments are always intuitive, rather than mathematical, because of the complexities of analyzing a nonlinear network. A straightforward, although abstract, argument in the final section of this paper proves decisively that all such attempts are doomed to failure. Such a proof, however, does not show why a particular scheme breaks down. For this reason, the major part of this paper is devoted to a detailed explanation of the behavior of the two generic types of nature-fooling circuits for second-harmonic generation. The arguments are not necessary to the conclusions of the paper, but are thought to be worth presenting for pedagogical reasons.

## IDEAL RECTIFIERS

An ideal rectifier is a lossless rectifier which can support no forward voltage drop, and can pass no reverse current:

$$v \leq 0, \quad i \geq 0, \quad vi \equiv 0, \quad \langle vi \rangle_t = 0, \tag{1}$$

where $\langle vi \rangle_t$ means the time average of $vi$. It follows that

$$\langle v \rangle_t \langle i \rangle_t \leq 0 \tag{1a}$$

with equality implying either $v \equiv 0$ or $i \equiv 0$. If the voltage and current are periodic, therefore expandable as:

$$\begin{aligned} v &= V_0 + \sum_{n>0} V_n \cos n\omega t + \sum_{n>0} U_n \sin n\omega t \\ i &= I_0 + \sum_{n>0} I_n \cos n\omega t + \sum_{n>0} J_n \sin n\omega t \end{aligned} \tag{2}$$

the dc power absorbed by the rectifier is

$$P_0 = V_0 I_0 = \langle v \rangle_t \langle i \rangle_t \leq 0, \tag{3}$$

or $-P_0$ is supplied to the load and the internal resistance, if any, of the source. The $n$th harmonic power absorbed by the rectifier is

$$P_n = (V_n I_n + U_n J_n)/2, \tag{4}$$

where $V_n$, $I_n$, $U_n$, and $J_n$ are the coefficients in the expansion (2). The total power absorbed by the rectifier is, by definition, the time average of the product $vi$:

$$P \equiv \langle vi \rangle_t = \sum_n P_n = 0. \tag{5}$$

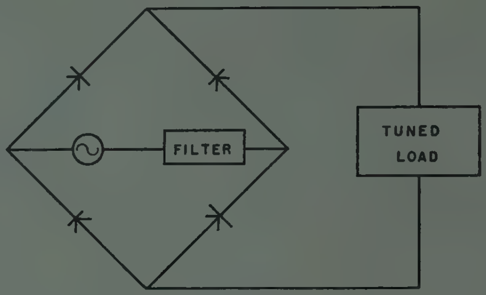

Fig. 1—Bridge-rectifier harmonic generator.

## ATTEMPTS TO AVOID DC DISSIPATION

It is often assumed to be obvious that suitable ideal tuned circuits make it possible to generate harmonics without dc dissipation.[1] Since by (3) and (1a), this implies either $v \equiv 0$ or $i \equiv 0$, the rectifier could be replaced by a short circuit or an open circuit, respectively, and *no* harmonics would be generated.

The scheme with an obvious flaw is shown in Fig. 1, where a simple bridge rectifier is used. The current through the load is supplied via the rectifiers, and cannot reverse. Similarly, the voltage across the load has the same polarity at all times, for the rectifier bridge is a short circuit for reverse voltage. Thus the load must have both dc current and dc voltage components, and dissipate dc power. Any selective circuits that avoid this situation will produce a condition of no current whatever through the load, hence an inoperative harmonic generator.

The other basic schemes are typified by second-harmonic generators using two diodes in a full-wave rectifier. Identical current waves are supplied alternately through the two diodes; each diode conducts during one half-cycle, and is nonconducting during the other half-cycle. Ideal tuned circuits or other selective filters are used to eliminate all harmonics other than the second from (1) the load current or (2) the load voltage.

## CASE (1): SECOND-HARMONIC CURRENT

Since the load current is supplied by the rectifiers (alternately) it cannot become negative. It is therefore of the form

$$i_L = I_0 + I_2 \cos 2\omega t, \qquad I_0 \geq |I_2|. \tag{6}$$

(The tuned load is supposed to make the dc load *voltage* vanish, to avoid dc power.) This load current requires the rectifier current shown in Fig. 2, and given by

$$i = \begin{cases} 0, & 0 \leq |\theta| \leq \pi/2 \\ I_0 + I_2 \cos 2\theta, & \pi/2 < |\theta| < \pi \end{cases} \tag{7}$$

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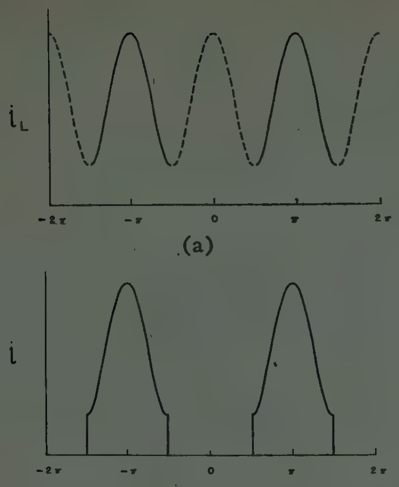
* Original manuscript received by the IRE, July 8, 1957; revised manuscript received, May 20, 1958.

† Natl. Bureau of Standards, Washington 25, D. C.

[1] See, *e.g.*, W. A. Edson, "Vacuum Tube Oscillators," John Wiley and Sons, Inc., New York, N. Y., p. 343; 1953.



(a)

(b)

Fig. 2—(a) Load current, $\theta=\omega t$, (b) rectifier current, $\theta=\omega t$.

This wave has the Fourier representation

$$i = \frac{I_0}{2} - \frac{2}{\pi}(I_0 + I_2/3)\cos\theta + \frac{I_2}{2}\cos 2\theta + \text{odd-harmonic cosines.} \tag{8}$$

Since the source is to supply power at fundamental frequency ($\omega$) only, and the load is to absorb power at dc and the second harmonic only, $v$ must contain no odd-harmonic cosines other than the fundamental. Therefore $v$ is of the form

$$v = -V_1\cos\theta + v_2, \tag{9}$$

where $v_2$ has no odd-harmonic cosine components, and should hopefully have no dc component. Partition $v_2$ into its even and odd parts. The odd part contributes no cosine terms. Split the even part into parts even and odd about $\theta=\pi/2$; these contribute even- and odd-harmonic cosines respectively. Therefore

$$v_2 = v_3 + v_4,$$

where $v_3$ is odd about zero, $v_4$ is even about zero and about $\pi/2$. During conduction ($\pi/2<|\theta|<\pi$), $v=0$, or $v_2=V_1\cos\theta$. Since $\cos\theta$ is even, we have

$$\left.\begin{aligned} v_3 &= 0 \\ v_4 &= V_1\cos\theta \end{aligned}\right\} \pi/2 < |\theta| < \pi,$$

so that

$$v_4 = -V_1|\cos\theta|, \text{ all } \theta \tag{10}$$

and has a nonzero dc component. The voltage across the rectifier is therefore

$$v = \begin{cases} -2V_1\cos\theta + v_3, & 0 \le |\theta| \le \pi/2 \\ 0, & \pi/2 < |\theta| < \pi \end{cases}, \tag{11}$$

where $v_3$ is an arbitrary odd function, subject to $v\le 0$. This condition at $\theta=0$ makes $V_1$ positive. Since $v_3$ is odd, it contributes sines only, and we have the Fourier expansion:

$$v = -\frac{2V_1}{\pi} - V_1\cos\theta - \frac{4V_1}{3\pi}\cos 2\theta + \text{even-harmonic cosines} + \text{sines.} \tag{12}$$

The powers absorbed by the rectifier are:

$$\begin{aligned} P_0 &= -V_1I_0/\pi, & P_1 &= V_1(I_0+I_2/3)/\pi \\ P_2 &= -V_1I_2/3\pi, & P_{n>2} &= 0, \end{aligned} \tag{13}$$

so that $V_1I_0/\pi$ is converted to dc, and $V_1I_2/3\pi$ to second harmonic. Since $I_0\ge|I_2|$ (6), the minimum dc power condition is

$$\begin{aligned} P_0 &= -V_1I_2/\pi, \qquad P_1 = 4V_1I_2/3\pi \\ P_2 &= -V_1I_2/3\pi \end{aligned} \tag{14}$$

or a second-harmonic efficiency of 25 per cent.

### CASE (2): SECOND-HARMONIC VOLTAGE

Let the load voltage have no harmonics other than the second:

$$v_L = -V_0 - V_2\cos 2\omega t. \tag{15}$$

The load power is supplied by the two rectifiers alternately, each working into a *load voltage* waveform like that of Fig. 2(a), without initial restriction on the magnitude or sign of $V_0$.

Since the rectifier is absorbing power at frequency $\omega$, and delivering power at dc and $2\omega$, we have a similar mathematical situation to that of Case (1); $i$ can contain no odd-harmonic cosines other than the fundamental, and is of the form

$$i = \begin{cases} 2I_1\cos\theta + i_3, & 0 \le |\theta| \le \pi/2 \\ 0, & \pi/2 < |\theta| < \pi \end{cases}, \tag{16}$$

where $i_3$ is an arbitrary odd function, subject to $i\ge 0$. $i$ does, however, contain all even-harmonic cosines, and arbitrary sines. If the *source* is to deliver power at $\omega$ only, and absorb no harmonic power, for all $i_3$,[2] the source voltage must contain no *even*-harmonic cosines, and no sines. The *source voltage* is therefore odd about $\pi/2$. Furthermore, during conduction ($0\le|\theta|\le\pi/2$) the source voltage equals the load voltage. These conditions yield the source voltage:

$$v_s = \begin{cases} -V_0 - V_2\cos 2\theta, & 0 \le |\theta| \le \pi/2 \\ V_0 + V_2\cos 2\theta, & \pi/2 < |\theta| < \pi \end{cases}. \tag{17}$$

The voltage across the rectifier is given by

$$v = v_L - v_s = \begin{cases} 0, & 0 \le |\theta| \le \pi/2 \\ -2(V_0 + V_2\cos 2\theta), & \pi/2 < |\theta| < \pi \end{cases} \tag{18}$$

where $V_0\ge|V_2|$ to satisfy $v\le 0$. The voltage expansion is

$$v = -V_0 + \frac{4}{\pi}(V_0 + V_2/3)\cos\theta - V_2\cos 2\theta + \text{odd-harmonic cosines} \tag{19}$$

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[2] This is restrictive, but simplifies the treatment. The generality of the result will be demonstrated in the final section of this paper.

while (16) yields

$$i = \frac{2I_1}{\pi} + I_1 \cos\theta + \frac{4I_1}{3\pi}\cos 2\theta + \text{even-harmonic cosines} + \text{sines}. \quad (20)$$

The various powers are:

$$P_0 = -2I_1V_0/\pi, \quad P_1 = \frac{2I_1}{\pi}(V_0 + V_2/3)$$
$$P_2 = -2I_1V_2/3\pi, \quad P_{n>2} = 0, \quad (21)$$

which is similar to the earlier result (13). The best efficiency is again 25 per cent.

*Generalization*[3]

Let

$$\begin{aligned} f(x) &\equiv \langle [v(t) - v(t-x)][i(t) - i(t-x)]\rangle_t \\ &= \langle -v(t-x)i(t) - v(t)i(t-x)\rangle_t \\ &\geq 0, \end{aligned} \quad (22)$$

since

$$v(t)i(t) \equiv 0, \qquad v(t_1)i(t_2) \leq 0,$$

with $v$ the voltage across a diode, $i$ the current through that diode. From (2)

$$\begin{aligned} v(t) - v(t-x) &= \sum V_n[\cos n\omega t - \cos n\omega(t-x)] \\ &\quad + \sum U_n[\sin n\omega t - \sin n\omega(t-x)] \\ &= \sum V_n[\cos n\omega t(1 - \cos n\omega x) - \sin n\omega t \sin n\omega x] \\ &\quad + \sum U_n[\sin n\omega t(1 - \cos n\omega x) + \cos n\omega t \sin n\omega x] \end{aligned} \quad (23)$$

with a similar form for $i(t) - i(t-x)$. Multiplying and averaging over $t$ yields

$$\begin{aligned} f(x) &= \frac{1}{2}\sum V_nI_n[(1 - \cos n\omega x)^2 + \sin^2 n\omega x] \\ &\quad + \frac{1}{2}\sum U_nJ_n[(1 - \cos n\omega x)^2 + \sin^2 n\omega x] \\ &= \sum (V_nI_n + U_nJ_n)(1 - \cos n\omega x) \\ &= 2\sum_{n>0} P_n(1 - \cos n\omega x). \end{aligned} \quad (24)$$

The vanishing of $(1 - \cos n\omega x)$ for $n = 0$ allows us to augment the sum in (24), with the result

$$f(x) = 2\sum_n P_n(1 - \cos n\omega x) \geq 0, \text{ all } x. \quad (25)$$

The losslessness of the rectifier gives

$$\sum_n P_n = 0 \quad (5)$$

so that

$$\sum_n P_n \cos n\omega x \leq 0. \quad (26)$$

If we write (26) as

$$P_0 + P_1 \cos\theta + \sum_{n>1} P_n \cos n\theta \leq 0$$

and (5) similarly as

$$P_0 + P_1 + \sum_{n>1} P_n = 0 \quad (27)$$

and eliminate $P_1$, we have

$$P_0(1 - \cos\theta) + \sum_{n>1} P_n(\cos n\theta - \cos\theta) \leq 0 \quad (28)$$

for each rectifier in the network.

For a network containing more than one rectifier, we let

$$P_n{}^t \equiv \sum_r P_n$$

or $P_n{}^t$ is the sum over all rectifiers of the $P_n$'s of the individual rectifiers. Summing (28) over rectifiers yields

$$P_0{}^t(1 - \cos\theta) + \sum_{n>1} P_n{}^t(\cos n\theta - \cos\theta) \leq 0. \quad (29)$$

But since power is supplied to the network at fundamental frequency $\omega$ only, we have

$$P_n{}^t \leq 0$$

for $n \neq 1$, and (29) can be rewritten:

$$\left|P_0{}^t\right|(1 - \cos\theta) + \sum_{n>1}\left|P_n{}^t\right|(\cos n\theta - \cos\theta) \geq 0, \text{ all } \theta \quad (30)$$

where $\left|P_0{}^t\right|$ is the dc power, and $\left|P_n{}^t\right|$ the $n$th-harmonic power, dissipated in the linear elements of the network. For $\theta \to 0$, this yields

$$\left|P_0{}^t\right|\theta^2/2 + \sum_{n>1}\left|P_n{}^t\right|(-n^2\theta^2/2 + \theta^2/2) \geq 0$$

or

$$\left|P_0{}^t\right| \geq \sum_{n>1}(n^2 - 1)\left|P_n{}^t\right| \quad (31)$$

as a lower limit on the dc power dissipated in the load for harmonic power dissipation.

From (27) and (31), we have

$$P_1{}^t = \left|P_0{}^t\right| + \sum_{n>1}\left|P_n{}^t\right| \geq \sum_{n>1} n^2\left|P_n{}^t\right| \geq n^2\left|P_n{}^t\right|$$

so that the $n$th harmonic cannot be generated with an efficiency exceeding $1/n^2$, even in the absence of other harmonics. The minimum dc dissipation is given by

$$P_n{}^t = 0, \qquad n > 2$$
$$\left|P_0{}^t\right| = 3\left|P_2{}^t\right|.$$

Inclusion of any higher harmonics in the load will *increase* $\left|P_0{}^t\right|$ by (31).

Using ideal rectifiers, at least 75 per cent of the converted power is dissipated as dc, and this cannot be reduced by any ingenious selective circuitry. Any harmonic generating circuit that is free from dc loss simply will not operate; only fundamental frequency voltages and currents will be present.

[3] For a complete generalization to nonideal rectifiers and other nonlinear positive resistance, see C. H. Page, "Frequency conversion with positive nonlinear resistors," *NBS J. Res.*, vol. 56, p. 179; 1956.

# An Error-Correcting Encoder and Decoder of High Efficiency*

J. H. GREEN, JR.†, AND R. L. SAN SOUCIE†

***Summary*—A report is given on a group effort which has demonstrated the applicability of regenerative shift register sequences to error-correcting codes. It is shown that a triple-error-correcting code of high efficiency can be formed by using the 15 cyclic permutations of a 15-bit, maximal-length, shift register sequence, a 15-bit zero sequence, and the 1-0 complements of the 16 sequences. It is further shown that the interrelationships between the bits of these binary sequences can be used to design a decoder of extreme simplicity.**

## INTRODUCTION

INTEREST in error-correcting codes has risen since the publication in 1948 of Shannon's now classic paper on the mathematical theory of communication systems.[1] Many papers since then have contributed to the present state of knowledge concerning error-correcting codes, and the large number of such papers makes a cataloging of them here almost impossible. The present work on error-correcting codes is the result of a group effort in the Advanced Development Department of the Amherst Engineering Laboratories of Sylvania Electronic Systems (see Acknowledgment).

The error-correcting codes to be described are derived from a special set of binary numbers known as "binary shift register sequences." These sequences can be generated in the following fashion. If a series of storage elements, *a* through *f*, is loaded with a succession of binary digits, as indicated in Fig. 1(a), we may perform modulo 2 addition on the contents of two or more storage cells. If the storage elements are connected as a shifting register, we may apply a shifting pulse that will transfer the contents of all storage elements one unit to the left. Simultaneously, we may introduce the result of the modulo 2 addition into the right-hand storage cell [Fig. 1(b)]. As this process is repeated, a succession of binary digits will pass through the storage element *a*. This sequence of binary digits, which we shall call a "word," will be periodic.

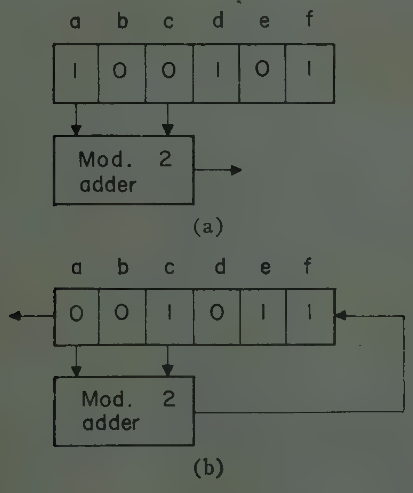

Fig. 1

For a shift register of length $n$, and for certain corresponding inputs from the register to the modulo 2 adder, the resulting word may be as long as $2^n-1$. Sequences of length $2^n-1$ generated in this manner are called maximum-length, shift register sequences, abbreviated "*m*-sequences," and have been studied by Huffman,[2] Golomb,[3] Zierler,[4] and others.

Three of the properties of *m*-sequences are of particular interest in our present discussion. First, during the $2^n-1$ shifts required to generate an *m*-sequence in a shifting register with $n$ storage units, every $n$-bit binary number (except the one consisting of all zeros) occurs once and only once in the $n$ storage elements. Second, if an *m*-sequence is compared element by element with any shifted version of itself (that is, a cyclic permutation of itself), one more disagreement than agreement results. (Mathematical derivations of these and related facts can be found.[3,4] Third, and most important of all, the nature of the generation process imposes certain interrelationships between the bits which facilitate the development of iterative decoders of extreme simplicity.

We shall describe the nature of the error-correcting code which has been chosen, the method by which it is generated, and a scheme for decoding. Equipment carrying out the processes to be described is currently in operation.

## GENERATION OF THE CODE

The basic encoding operation may be described as the mapping of the usual 32, five-bit binary numbers associated with the standard radio teletype code into 32, fifteen-bit binary numbers.

This expansion provides the transmission of two re-

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† Sylvania Electronics Sys., Amherst Eng. Labs., Williamsville, N. Y.

[1] C. Shannon, "A mathematical theory of communication," *Bell Sys. Tech. J.*, vol. 27, pp. 379–423, 623–656; July and October, 1948.

[2] D. A. Huffman, "The synthesis of linear sequential coding networks," *Proc. 3rd London Symposium on Information Theory*, pp. 77–95; 1955. Published by Academic Press, New York, N. Y.; 1956.

[3] S. W. Golomb, "Sequences with randomness properties," Terminal Prog. Rep. under Contract Req. No. 639498, Account No. 7570-505-739, Glen L. Martin Co., Baltimore, Md.; June 14, 1955.

[4] N. Zierler, "Linear recursive sequences, I," Group Rep. 34-63, Lincoln Labs., M.I.T., Lexington, Mass.; December 2, 1957.

dundant bits for each bit of true information. It should be noted, however, that this particular degree of redundancy applies only to this example and to the equipment which has been constructed. It is not, therefore, a basic characteristic of the encoding technique to be discussed. The 32, fifteen-bit sequences, or words, which form the alphabet may be described as follows.

If we establish a shifting register having four storage elements, and read from the first and second storage elements into a modulo 2 adder, we will find that by shifting and regenerating in the fashion described in the preceding paragraphs, we can generate the following sequence:

$$111100010011010. \tag{1}$$

We can generate a second sequence in a substantially identical process by substituting for the modulation 2 addition in the feedback circuit what we shall call complementary modulo 2 addition, which is defined by Table I.

TABLE I

| $B$ / $A$ | 0 | 1 |
|---|---|---|
| 0 | 1 | 0 |
| 1 | 0 | 1 |

The sequence that results from complementary modulation 2 addition,

$$000011101100101, \tag{2}$$

is the 1 for 0, 0 for 1, complement of our original sequence.

We are now in a position to describe the 32 characters in our error-correcting alphabet. We have, first, the 15 cyclic permutations of sequence (1) (called subset A) and, secondly, the 15 cyclic permutations of sequence (2) (called subset B). In addition, we include the special cases in which the shifting register contains all zeros and all ones. It should be noted at this point that all 32 of the $m$-sequences can be generated with two basic generators, given the proper starting conditions in the storage elements.

Before discussing the method of generation further, let us first examine the error-correcting capabilities of our alphabet. Five cases are easily recognized. First, if any pair of sequences is selected, both from subset A (or both from subset B), direct examination will show that there exist 7 positions in which the 2 sequences agree and 8 positions in which they disagree. Second, if a fixed but arbitrary member of subset A is compared with each member of subset B, except for its 1-0 complement, we find 8 positions in which the sequences agree and 7 in which they disagree. On the other hand, if this fixed sequence is compared with its 1-0 complement, it disagrees in all 15 positions. Third, the sequence of all ones agrees in 8 positions and disagrees in 7 with the members of subset A, whereas it agrees in 7 positions and disagrees in 8 positions with the members of subset B. Fourth, the sequence of all zeros agrees in 7 and disagrees in 8 positions with the members of A and it agrees in 8 and disagrees in 7 positions with the members of B. Fifth, the sequence of all ones disagrees in 15 positions with the sequence of all zeros. Hence, it is true in all cases that if any one of the sequences in our alphabet has been modified by 3 errors, 3 changes will be required to restore the word to its error-free form, while at least 4 changes will be required to change it into any other member of the alphabet.

We therefore have a 32-character, 15-bit, triple-error-correcting code with a Hamming distance[5] of 7. In the paper cited, Hamming shows that a 15-bit, quadruple-error-correcting code (Hamming distance 9) would contain fewer than 17 words. Since 32 characters are needed for standard radio teletype, a 15-bit, quadruple-error-correcting code of this kind does not exist, and thus our code cannot be improved in this direction.

Although maximum-length, shift register sequences constitute an efficient error-correcting system, many other efficient codes exist. The main justification for our interest in $m$-sequences arises from the ease with which they may be generated and decoded. As we have indicated, it is possible to generate sequences by regenerative shift registers of the type illustrated in Fig. 1(a) and 1(b). The members of subset A and the sequence consisting of all zeros can be generated with a feedback logic that uses modulo 2 addition, whereas the members of subset B and the sequence containing all ones can be generated with a feedback logic that uses complementary modulo 2 addition.

In practice, of course, we would like to generate all the characters of our alphabet from the same generator; we shall now proceed to demonstrate that this is possible. We have stated that the sequences in subset A can be generated with a feedback logic that uses modulo 2 addition. If we label the digits of that sequence $A$, $B$, $C$, $D$, $E$, $F$, $\cdots$, $O$, we can write $A+B=E$; that is, the digit $A$ added to digit $B$ gives digit $E$, by mokulo 2 addition. Since the sequence is regenerative, $B+C=F$, modulo 2. If we use the properties of modulo 2 addition, we can rewrite these equations as

$$A + B + E = 0 \tag{3}$$

$$B + C + F = 0. \tag{4}$$

Clearly, the sequence consisting of all zeros also satisfies (3) and (4). The sequences in subset B, on the other hand, satisfy

$$A + B + E = 1 \tag{5}$$

$$B + C + F = 1, \tag{6}$$

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[5] R. W. Hamming, "Error-detecting and error-correcting codes," *Bell Sys. Tech. J.*, vol. 26, pp. 147–160; April, 1950.

where addition is now complementary modulo 2. Also, the sequence consisting of all ones satisfies (5) and (6). Adding (3) and (4), with modulo 2 addition gives

$$A + C + E + F = 0, \tag{7}$$

while adding (5) and (6) with complementary modulo 2 addition gives

$$A + C + E + F + 1 = 1 \tag{8}$$

or

$$A + C + E + F = 0. \tag{9}$$

Thus, in either case we have

$$A + C + E = F, \text{ modulo 2.} \tag{10}$$

It is therefore possible to generate all 32 members of our alphabet in a shifting register with 5 storage elements by reading the contents of the first, third, and fifth storage elements into a modulo 2 adder (where the addition may now be either modulo 2 addition or complementary modulo 2 addition), and by causing the shift register to regenerate in the manner described in our previous examples.

We now inject a 5-bit information character into the 5 storage elements of the shift register, and pulse the shift line 15 times. The sequence read out of the first storage element of the shift register is then the 15-bit character of our error-correcting alphabet that corresponds to the 5-bit information character which is to be transmitted.

## DECODING

The 32 characters of our coding alphabet can be divided into 2 subsets of 16 words each, as we have shown. One subset consists of those sequences wherein the first, second, and fifth elements sum to zero by modulo 2 addition. The other subset consists of those sequences wherein the first, second, and fifth elements sum to zero by complementary modulo 2 addition. Although we have derived relationships which are invariant for both groups, it proves to be more conservative of equipment to decode the two groups separately. We shall first show how the decoding process can be applied to the 16 characters obtained by modulo 2 addition, and then indicate how the remaining 16 characters are decoded. We shall indicate how the equipment simultaneously decides into which of the 2 subsets a received sequence belongs. It is emphasized that the particular decoding scheme which is to be outlined has been selected because of its simplicity and economy in the use of equipment. Improvements in error-correcting capabilities can be made by modifying our techniques; many such avenues are known to us. However, we feel that such improvements would cause the sacrifice of equipment simplicity and size. We have deliberately favored simplicity.

Let $a_1, a_2, a_3, \cdots, a_{15}$ be any one of the 16 sequences that obey the law: $a_1+a_2=a_5$, modulo 2. It follows that $a_2+a_3=a_6$, modulo 2, $a_3+a_4=a_7$, etc. We may use these basic relationships to derive seven independent expressions for $a_1$:

$$a_1 = a_2 + a_5$$

$$a_1 = a_3 + a_9$$

$$a_1 = a_4 + a_{15}$$

$$a_1 = a_6 + a_{11}$$

$$a_1 = a_7 + a_{14}$$

$$a_1 = a_8 + a_{10}$$

$$a_1 = a_{12} + a_{13}.$$

In addition we have $a_1=a_1$. If there are errors in positions $a_1$, $a_2$, through $a_{15}$, equations containing these errors may produce incorrect results. For 3 errors in the received 15 bits, we can therefore have as many as 3 of the 8 equations in error when we select the value of $a_1$ indicated by the majority of the 8 independent equations. We will arrive at the correct value, however, since 5 of the 8 equations will produce the correct answer and 3, the incorrect answer. (If more than 3 errors cause a tie among the 8 solutions, we arbitrarily set $a_1=1$.)

Since the equations in the aforementioned derivation are cyclic, we have a second set of equations which may be solved to give a value for $a_2$. In practice, we can solve for $a_2$ with the identical circuitry used to solve for $a_1$. This is accomplished by the simple procedure of shifting all elements in the shifting register 1 unit to the left and repeating the identical operation. Similarly we solve for $a_3, a_4, \cdots, a_{15}$. The point made in this paragraph is the crucial one from the standpoint of decoding simplicity: each of the bits is decoded with the same circuitry. The decoding scheme, therefore, has been implemented with very simple equipment.

As we have indicated in the Introduction, it is neither feasible nor relevant to the present discussion to enumerate the many error-correcting codes which are now in the literature. It seems prudent, however, to mention here that the so-called "Reed-Muller codes"[6] are similar to the codes under discussion.

In particular, the Reed-Muller codes have length $2^n$ and may be encoded in a relatively simple manner. The Reed-Muller decoding scheme is the following. Assume that the code sequences are of length 16 so that the redundancy is 16/5. Four of the 5 information bits are obtained by solving 4 sets of 8 equations each and taking a majority vote of the solutions. The fifth information bit is obtained in a different way. Because the solution for 4 information bits involves 4 different sets of 8 equations, it is not possible to use identical circuitry for these solutions. It therefore follows that the equipment complexity increases.

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[6] I. S. Reed, "A class of multiple-error-correcting codes and the decoding scheme," IRE TRANS. ON INFORMATION THEORY, vol. IT-4, pp. 38–49; September, 1954.

The process of solving the equations, both by modulo 2 and complementary modulo 2 addition, and selecting the proper answer is a simple one in practice. While the error-correction process is being performed, the results of the solution of the 7 simultaneous equations are compared, position by position, with the contents of the storage register which was filled by the incoming signal. If the sequence transmitted was generated by modulo 2 addition, the output of the error decoder and the contents of the register will agree except for those positions in which errors occur. If this agreement is observed, the error-correcting process is repeated and the decoder information character is read directly from a storage register. If, however, the character transmitted was generated by complementary modulo 2 addition, the result of the decoder operation and the contents of the incoming message storage register will disagree in all positions except those which contain errors. If this disagreement is noted, the complement of the error-corrected information character is read out of the storage register from the opposite plates of the flip-flop storage units.

The ability to indicate a preponderance of agreements or disagreements will not fail until the number of errors received is greater than 7. This capability far exceeds the ability of the error decoder to correct 3 errors or less. Therefore, decoder operation will not fail for any combination of errors that the error corrector can basically decode.

The decoding process also takes advantage of additional information which is usually present when signals are transmitted by means of radio circuits. In radio teletype transmission, for example, frequently signals in both mark and space channels are absent, which indicates that fading is present on the circuit; or signals are present in both mark and space channels, indicating that interference has taken place. The output of the radio teletype receiver will therefore indicate that the output is a mark or a space; or because of fading or jamming, no information is available. In the case where no information is available, an omission signal is transmitted to the error decoder. This omission signal is then used to eliminate the associated equation from the decision being made. For 2 omissions, therefore, 6 independent equations remain to be solved rather than 8, for 3 omissions there remain 5 equations solved, and so forth. Since 3 omissions will leave 5 useful equations, and since 5 useful equations will always give a correct solution even in the presence of 2 errors, the error decoder can provide the correct result even in the presence of 2 errors and 3 omissions. The translation of doubtful information into omissions is therefore a substantial improvement over systems which must evaluate received signals either as marks or spaces without the option of rejecting doubtful information.

## Acknowledgment

The results reported in this paper represent the integrated contributions of a group of mathematicians and engineers who investigated coding techniques. Major contributors were M. G. Nicholson, Jr., manager of the Advanced Development Department, Amherst Engineering Laboratories, R. T. Barnes, R. G. Fryer, Jr., and James H. Green, Jr. It has been the privilege of the authors of this paper to report upon the work of this group.

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# A Computer Oriented Toward Spatial Problems*

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*Summary*—A general purpose digital computer can, in principle, solve any well defined problem. At many tasks, such as the solution of systems of linear equations, these machines are thousands of times as fast as human beings. However, they are relatively inept at solving many problems where the data is arranged naturally in a spatial form. For example, when it comes to playing chess or recognizing sophisticated patterns, present day machines cannot match the performance of their designers.

The difficulty in such cases appears to be that conventional computers can actively cope with only a small amount of information at any one time. (This circumstance is aptly illustrated by the title of an article by Samuel,[1] "Computing Bit by Bit.") It appears that efficient handling of problems of the type mentioned above cannot be accomplished without some form of parallel action.

A stored program computer is described which can handle spatial problems by operating directly on information in planar form without scanning or using other techniques for transforming the problem into some other domain. The order structure of this machine is explained and illustrated by a few simple programs. An estimate of the size of the computer (based on one possible design) is given. Programs have been written that enable the machine to recognize alphabetic characters independent of position, proportion, and size.

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† Bell Telephone Labs., Inc., Whippany, N. J.

[1] A. L. Samuel, "Computing bit by bit," Proc. IRE (Computer Issue), vol. 41, pp. 1223–1230; October, 1953.

## INTRODUCTION

THE stored program digital computer has been in existence for about a decade and has proven itself to be a powerful and versatile instrument. Roughly speaking, any solvable problem can be solved by a digital computer. At many tasks, such as the solution of systems of linear equations, these machines are thousands of times as fast as human beings.

However, there are certain tasks, which might be termed spatial problems, at which digital computers are relatively inept. For example, it seems to be extremely difficult to write chess playing programs that will enable a computer to compete successfully with a capable human opponent.[2] Pattern recognition is another area in which present day machines cannot match the performance of their designers. Some important and interesting work done in this field is described in the literature.[3–5]

The difficulty in such cases appears to be that these machines can actively cope with only a small amount of information at any one time. (This circumstance is aptly illustrated by the title of an article by Samuel.[1]) It appears that efficient handling of problems of the type mentioned above cannot be accomplished without some form of parallel action.

An important implication of this argument is that machines of greater complexity are needed. This, however, should not be regarded as an insurmountable barrier, since it is likely that great advances will be made in the components field during the next decade.

The principal objective of the research reported on here is to learn how to build machines that can efficiently solve problems not well suited to solution by conventional digital computers.

The approach is to attempt to describe a computer inherently well matched to one such problem (pattern detection), hoping that such a computer, probably in an improved version, will then perform well when faced with a much larger class of problems.

## GENERAL STRUCTURE OF THE COMPUTER

Fig. 1 illustrates the form of the proposed machine. It consists of a master control and a rectangular array of modules. Each module communicates with its four immediate neighbors and receives orders from the master control. The master control cannot address the modules individually, but issues general orders which go to all of the modules.

A module consists of a one-bit accumulator, a small amount of random access memory (perhaps six bits in one-bit words), and some associated logic. Inputs to each module come from the master control and from the accumulators of the modules above, below, to the left, and to the right of it. We also assume that an input signal may be fed directly to each accumulator from outside the machine.

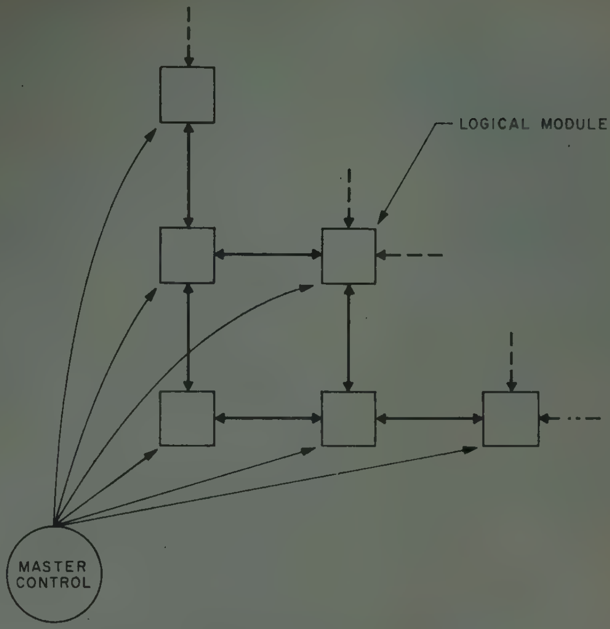

Fig. 1—Organization of spatial computer.

The master control includes a random access memory for storing instructions, a clock, and decoding circuits. It acts like the operation decoding section of a conventional digital computer, reading out instructions from memory in sequence, decoding them, and sending appropriate control voltages out on a set of buses feeding the modules.

A logical adder (OR-gate) with an input from each module accumulator tells the master control if all of the accumulators have zeros in them, and thereby makes possible the use of a transfer on zero order. This instruction, analogous to the conditional transfer orders used in ordinary digital computers, tells the master control to skip to the instruction addressed by the transfer zero order if there are no ones in any of the module accumulators. It is the only decision order which we use.

## ORDER STRUCTURE (SUMMARIZED IN TABLE I)

The transfer on zero order (abbreviated trz $x$) has just been described. In addition there is an unconditional transfer (tr $x$) which simply changes the contents of the instruction counter to correspond to address $x$.

As was stated before, each module has a small number of individually addressable one-bit memory elements. Within a module we shall refer to these registers as $a$, $b$, $c$, *etc.* The instruction store $b$ (st $b$) tells each module to store the contents of its accumulator in the $b$th memory register (without altering the accumulator contents). Similarly write $b$ (wr $b$) orders the contents of each $b$ register to be written into the accumulator (without changing the contents of $b$).

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[2] J. Kister, *et al.* "Experiments in chess," *J. Assoc. Comp. Mach.*, vol. 4, pp. 174–177; April, 1957.

[3] O. G. Selfridge, "Pattern recognition and learning," presented at the Symposium on Information Theory; London, Eng.; September, 1955.

[4] O. G. Selfridge, "Pattern recognition and modern computers," *Proc. of the Western Joint Comp. Conf.*, pp. 91–93; March, 1955.

[5] G. P. Dinneen, "Programming pattern recognition," *Proc. of the Western Joint Comp. Conf.*, pp. 94–100; March, 1955.

TABLE I

ORDER STRUCTURE

| Order | Abbreviation | Meaning |
|---|---|---|
| Transfer to instruction $x$. | tr $x$ | Execute instruction $x$ next. |
| Transfer on zero to instruction $x$ | trz $x$ | Execute instruction $x$ next if there are no ones in the field. Otherwise continue in the normal sequence. |
| Invert | in | Change the contents of all the accumulators. |
| Add | add | Add logically to the contents of the accumulator the contents of the specified memory cells and neighboring accumulators. Leave memory cell contents unchanged. |
| Multiply | mpy | Multiply logically the contents of the accumulator and the specified memory cells and adjacent accumulators. Result is placed in accumulator and memory cell contents are left alone. |
| Add in memory | adm | Add logically to the contents of each of the specified memory cells the contents of the accumulator. Do not change accumulator contents. |
| Multiply in memory | mpm | Multiply logically the contents of each specified memory cell by the contents of the accumulator without disturbing the accumulator. |
| Store | st | Store the accumulator contents in each specified memory cell without disturbing the accumulator. |
| Write | wr | Write the contents of the indicated memory cell into the accumulator without altering the contents of the memory cell. |
| Shift left (or right, or up, or down) | sL (sR, sU, sD) | Write the contents of each accumulator into the accumulator to the left (or right, or above, or below). |
| Add reference | Add ref | Add a one to accumulator of module in lower left corner of matrix. |
| Link | Link | Record in memory elements located between adjacent pairs of modules, whether or not ones are contained in both accumulators. (Diagonally touching modules are considered as adjacent for this order and the next one.) |
| Expand | exp | Add ones to the accumulators of those modules connected through a chain of active inter-module memory elements of the kind specified in the order (horizontal, vertical, positive diagonal, or negative diagonal) to some module with a one in its accumulator. |
| Shift around | sA | Same as shift right except that rightmost modules of each row send contents to left most module of row above, lower left module gets bit from input register, and upper right module sends contents to output register. |

Information can be transmitted directly from one module to another by means of a shift instruction. A shift right (sR) order for example, causes the contents of each accumulator to be transferred to the accumulator of the module to the right of it. Shift left (sL), shift up (sU), and shift down (sD) have analogous meanings. (When the shift orders are used we assume that the matrix is bordered by modules having zeros in their accumulators.)

The invert order (in) causes the contents of each accumulator to be complemented. Logical addition and multiplication[6] can be carried out among the contents of the accumulator, memory registers, and neighboring accumulators. Add $x$ causes the contents of memory register $x$ to be added logically to the contents of the accumulator. The result is stored in the accumulator and the contents of $x$ are left unaltered. The add left (add $L$) order causes the contents of each accumulator to become the logical sum of the original contents of that accumulator and the original contents of the accumulator of the module to the left. Add right (add $R$), add up (add $U$), and add down (add $D$) have similar meanings. Any combination of the contents of neighboring accumulators and memory registers may be added to the accumulator contents in the above manner using a single order. For example, if we wish to add to the contents of each accumulator the contents of memory registers $a$ and $c$ (of the same module) and the contents of the accumulator above then we would use the order add $a$, $c$, $U$.

A completely analogous set of instructions exists for a logical multiplication. Thus mpy $b$, $D$ would cause the original accumulator contents to be multiplied by the contents of memory registers $b$ and contents of the accumulator below. Result appears in the accumulator, and contents of the memory registers remain unchanged.

The order add in memory (adm $b$) causes the logical sum of the accumulator contents and the contents of register $b$ to appear in $b$, without altering the accumulator contents. The accumulator contents can be added simultaneously to any number of memory registers by an order adm, $a$, $b$, $d$, for example. Note that separate additions are made into each memory register, each sum involving the accumulator contents and the contents of one memory register. A similar set of orders exists for multiplication—for example mpm $b$, $d$, *etc.*

The add reference order (add ref.) causes a one to be added to the accumulator of the module in the lower left corner of the matrix. Note that, in contrast to the

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[6] Logical addition is defined by the equations:

$$1+0=0+1=1+1=1 \text{ and } 0+0=0.$$

Logical multiplication is defined by the equations:

$$1\times 0=0\times 1=0\times 0=0 \text{ and } 1\times 1=1.$$

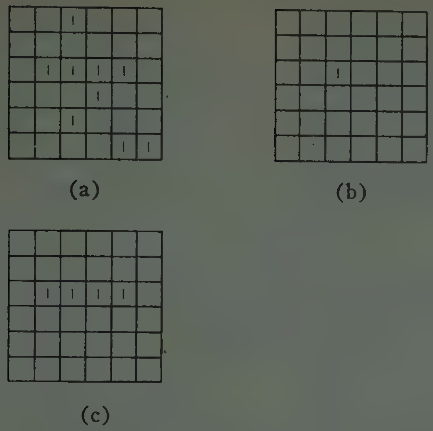


Fig. 2—Expansion example.

previously described orders, add reference does not treat all modules alike.

A few new definitions at this point may help to facilitate the discussion. Module accumulators will be referred to as *cells* (sometimes *one-cells* or *zero-cells*, depending on their contents) when we discuss their contents as parts of an over-all pattern. The arrays of ones and zeros contained in the accumulators or in a particular set of memory elements (say the *b*-registers) will be termed *fields*.

Inputs to the matrix can be made in parallel by associating an input device (perhaps a photocell) with each module. The shift-around order (SA) provides a simple method for serially loading and unloading the matrix. A single bit is transmitted to the accumulator of the lower left module from an external source. At the same time the contents of each cell is transmitted to the cell to the right (as in the shift right order) except for the right-most cell of each row, which sends its contents to the left-most cell in the row above. The upper right corner module transmits to an output register. Thus a new pattern can be loaded into the matrix while the old contents are simultaneously taken out.

In certain pattern processing operations it is desirable to obtain an output from the master control instead of from the network. For example, in a recognition problem we would want the machine to identify the input pattern as a particular member of some alphabet. This might be done by means of the conditional transfer order and an order enabling the machine to send out pulses on one or more members of a set of output buses.

We shall not go into further detail regarding input-output problems, since these questions are intimately related to the specific tasks being performed.

The link and expand orders are used together and require a somewhat more elaborate explanation due to the fact that, unlike the previously described orders, they permit the contents of a cell to be directly affected by the contents of arbitrarily distant cells.

Connectivity is an important concept in spatial operations. For example: Given a particular cell of the matrix (called a *basis* point) we might wish to find all points in a given field connected to that cell through a chain of horizontally linked one-cells. This problem is illustrated in Fig. 2. Fig. 2(b) shows the location of the basis point which is to be *expanded* horizontally ($H$) over the field shown in Fig. 2(a). The result of this expansion operation appears in Fig. 2(c).

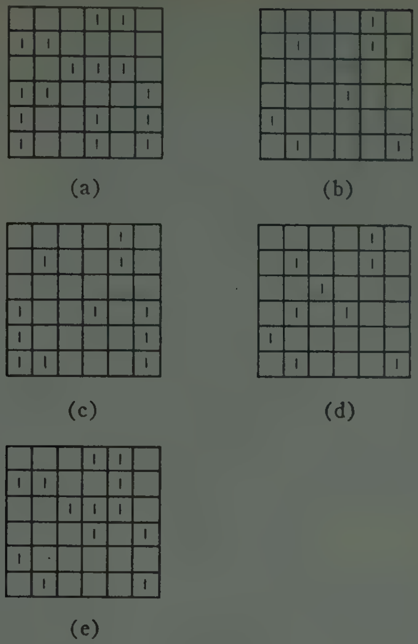


Fig. 3—More complex expansions.

To accomplish this with the link-expand orders we would write the *a*-field in the accumulators and give the order "link." Then (possibly many steps later) we would write the *b*-field in the accumulators and give the order "exp $H$." The same idea can be used to expand a set of basis points over a field. In Fig. 3 we expand Fig. 3(b) vertically over Fig. 3(a) to obtain Fig. 3(c).

Expansions along diagonal lines can also be defined for either positive or negative slopes ($D_P$ and $D_N$, respectively). The results of a $D_P$ expansion of Fig. 3(b) over Fig. 3(a) is shown in Fig. 3(d).

Expansions simultaneously involving several types of connectivity are also possible. For example, we might wish to consider two points as being connected if it is possible to move from one to the other in single steps which are either diagonal with negative slope or vertical and which pass through one-cell. Thus Fig. 3(e) shows the result of an $H$, $D_N$ expansion of Fig. 3(b) over Fig. 3(a). Note that the results of an exp H order followed by an exp $D_N$ order is *not* in general the same as the result of an exp $H$, $D_N$ order.

Subroutines using simpler instructions can be written for any expansion, but the importance of this process probably justifies the added circuitry required to shorten their execution times by a substantial amount.

## SOME SIMPLE PROGRAMS

Some elementary programs are now presented to illustrate the use of the orders.

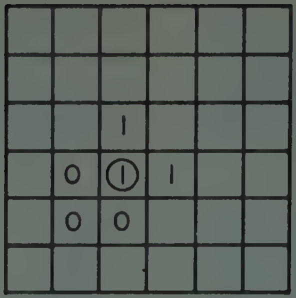


Fig. 4—Lower left corner point.

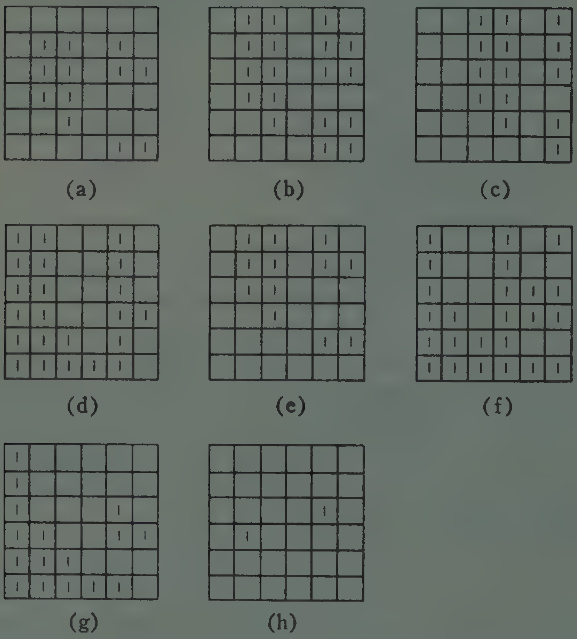

(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 5—Detection of lower left corner point.

### *Example 1: Detecting Lower Left Corners*

Locate all lower left corners in a given field, where a lower left corner is defined as a one-cell with one-cells both above and to the right, and with zero-cells to the left, below and diagonally (lower left) adjacent, as typified by the circled one in Fig. 4. (In Fig. 4 the unmarked cells can contain either zeros or ones.)

We illustrate the program by referring to Fig. 5, where Fig. 5(a) is assumed to be the initial field in the accumulators. (From now on unmarked cells in our diagrams are understood to be 0-cells.)

| | |
|---|---|
| 1) st *a* | |
| 2) add *D* | Result shown in Fig. 5(b). |
| 3) sR | See Fig. 5(c). |
| 4) in | See Fig. 5(d). |
| 5) st *b* | The field shown in Fig. 5(d) is stored in the *b*-registers. |
| 6) wr *a* | The original field [Fig. 5(a)] is written into the accumulators. |
| 7) sU | See Fig. 5(e). |
| 8) in | See Fig. 5(f). |
| 9) mpm *b* | The product of fields Fig. 5(d) and Fig. 5(f), shown in Fig. 5(g) appears in the *b*-registers. The ones in this result designate those points in the original field which are oriented with respect to three zeros in the same manner as the circled one in Fig. 4. |
| 10) wr *a* | Again field [Fig. 5(a)] is written into the accumulators. |
| 11) mpy *U*, *R*, *b* | The resulting field, shown in Fig. 5(h) has ones at the two locations which are lower left corners in the original field. |

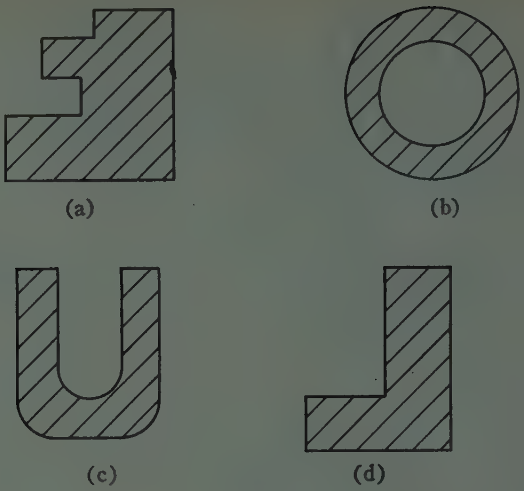
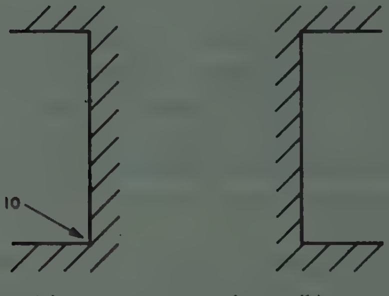

(a) (b) (c) (d)

Fig. 6—Vertical concavity.



(a) (b)

Fig. 7—Characteristic features of vertically concave figures.

### *Example 2: Detecting Vertical Concavity*

A figure will be said to be vertically concave if it is possible to connect two points on the figure with a vertical line which falls outside the figure at some point between the given points. Fig. 6(a) and Fig. 6(b) depict vertically concave figures, whereas Fig. 6(c) and Fig. 6(d) depict vertically convex figures.

In this example, a program is presented for selecting from an arbitrary field all vertically concave figures. Every vertically concave figure has a portion of the form of Fig. 7(a) or of Fig. 7(b) (the vertical part might be only one unit long) and so the problem can be solved by selecting all figures having one or both of these features.

Beginning with the given field in the accumulators, the program is as follows:

| | |
|---|---|
| 1) st *a* | |
| 2) sR | |
| 3) in | |
| 4) mpy *a* | Locates all left edge points. |
| 5) link | |
| 6) st *b* | |
| 7) wr *a* | |
| 8) mpy *L*, *U* | |
| 9) sU | |
| 10) mpy *b* | Yields lower inside corner points on left edges [see point labelled (10) in Fig. 7(a)]. |
| 11) exp *V* | At this point the accumulators contain all vertical edges facing left which start from inside corner points as described in 10) above. |
| 12) st *b* | |
| 13) wr *a* | |
| 14) mpy *L*, *D* | |
| 15) sD | |

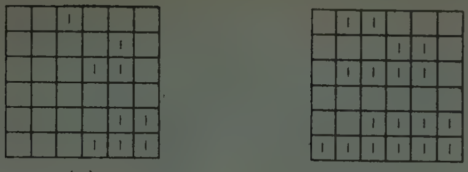

(a) (b)

Fig. 8—Line doubling.

| | |
|---|---|
| 16) mpy *b* | The accumulators now contain upper inside corner points on left edges that also have lower inside corner points. That is, we have found points on all figures having the feature described in Fig. 7(a). |
| 17) st *c* | |
| 18) wr *a* | |
| 19–32) | Repeat steps 2–16, interchanging *L* and *R* in all places so as to obtain points in the accumulator corresponding to the feature shown in Fig. 7(b). |
| 33) adm *c* | In the *c*-registers we now have at least one point on every vertically concave figure. |
| 34) wr *a* | |
| 35) link | |
| 36) wr *c* | |
| 37) exp $V, H, D_N, D_P$ | Only vertically concave figures remain in the accumulators. |

### *Example 3: Line Doubling Program*

The object of this program is to extend every horizontal line of ones to the left, by its own length. Thus, if the initial field is as shown in Fig. 8(a), the resulting field will be the one in Fig. 8(b).

The program (one of the few which we have found to require a loop) is as follows (the initial field is in the accumulators):

| | |
|---|---|
| 1) st *a* | |
| 2) sL | |
| 3) adm *a* | |
| 4) mpy *R* | Eliminates a point from the right end of each line. |
| 5) trz 7 | |
| 6) tr 2 | One point has been added to the left end of each line in Fig. 8(a). |
| 7) wr *a* | The desired field is now in the accumulators. |

## LOGIC FOR THE DISTRIBUTED COMPUTER

A logical diagram for a typical module of a computer realizing the order structure of Table I is shown in Fig. 9. Flip-flops are used for the accumulator and for the memory registers. (Only three memory registers are shown, but it is easy to see how others can be added.)

Five order leads enter the module from the master control. They are add, multiply, add in memory, multiply in memory, and invert. An additional lead from the master control refers to each of the four neighboring modules, and there is also a lead corresponding to each memory register.

The instructions, add, mpy, mpm, adm, and invert, are given by pulsing the appropriate order lead and the desired set of address leads (these may be memory register addresses or references to adjacent modules). The instructions, write or shift are given by pulsing both the add and the mpy leads, and the store order is given by pulsing both the adm and the mpm leads.

Note that with this sytem of logic the mpm and adm instructions require no additional logic, and only one additional order lead once the store order has been mechanized. The mpy and add orders are similarly related to the write order.

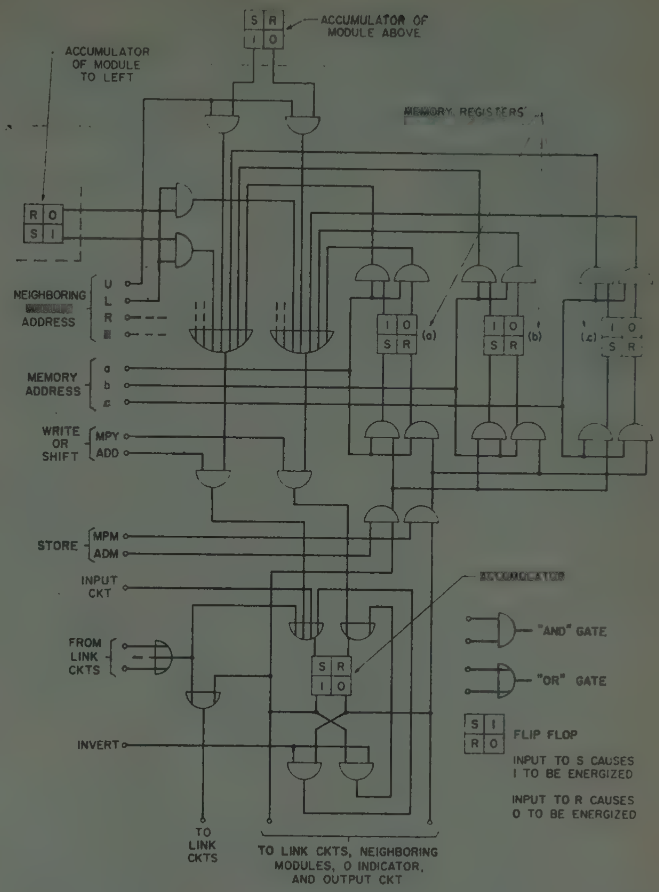
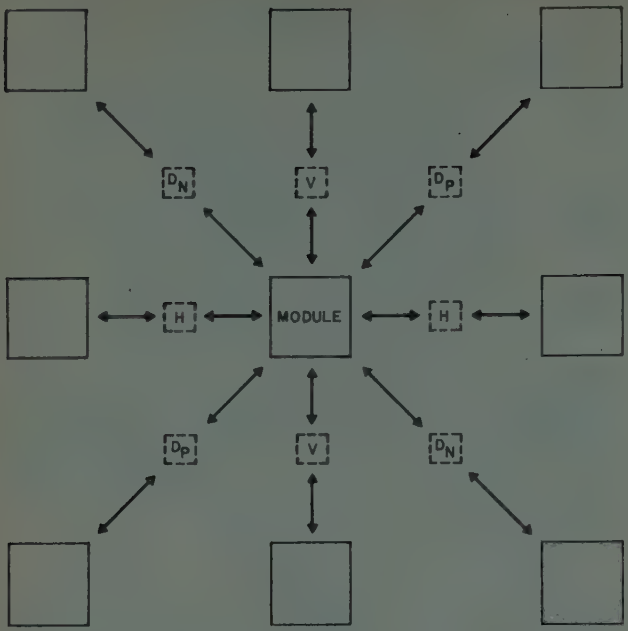

S R
I O
ACCUMULATOR OF MODULE ABOVE
ACCUMULATOR OF MODULE TO LEFT
MEMORY REGISTERS
R O
S I
NEIGHBORING MODULE ADDRESS
U
L
R
D
I O
S R
(a)
(b)
(c)
MEMORY ADDRESS
a
b
c
WRITE OR SHIFT
MPY
ADD
STORE
MPM
ADM
INPUT CKT
ACCUMULATOR
FROM LINK CKTS
INVERT
"AND" GATE
"OR" GATE
S I
R O
FLIP FLOP
INPUT TO S CAUSES I TO BE ENERGIZED
INPUT TO R CAUSES O TO BE ENERGIZED
TO LINK CKTS
TO LINK CKTS, NEIGHBORING MODULES, O INDICATOR, AND OUTPUT CKT

Fig. 9—Module logic.

In order to carry out the link and expand orders, the direct intermodule connections must be supplemented by special circuitry which will be termed link circuits. These are placed between every adjacent pair of modules. Fig. 10 shows the eight link circuits connecting a particular module to its neighbors. Note that whereas diagonally adjacent modules are not connected by direct lines, they are connected through link circuits.

The logic necessary in the link circuits is shown in Fig. 11. When a pulse is applied to the link terminal from the central control, the flip-flop will be placed in the one-state, if, and only if, ones were present in both of the cells connected by the circuit. (This setting remains unchanged until another link order is given.) If the flip-flop is in the one-state, then a pulse appearing on the expand *V* lead (we are considering a vertical link circuit) will cause a one appearing at the output of either of the accumulators of the linked modules to appear at *both* the input and output terminals of the other accumulator. (Strictly speaking, the ones appear not at the outputs of the accumulator but at the outputs of OR-gates driven by the accumulators.) Ones can thus be propagated through the matrix as fast as the logic permits since they can pass through modules without waiting for the accumulators to be activated.

The central control unit consists of a random access memory, a clock, an order decoder, and some input-output control circuitry. No significant departures from the arrangements used in conventional computers are necessary.



$V$ = vertical link circuits.
$H$ = horizontal link circuits.
$D_P$ = link circuits on positively sloped diagonal.
$D_N$ = link circuits on negatively sloped diagonal.

Fig. 10—Arrangement of link circuits.

## Conclusions

The spatial computer described here is a versatile tool for solving problems in which the data to be manipulated occur in large blocks which are locally correlated.

In the field of visual pattern detection, a prime example of this sort of problem, some powerful techniques have been developed for using this machine. These will be reported on at a later date. Other applications of the spatial computer remain to be explored.

The logical scheme presented in the preceding section for realizing the machine calls for about 170 gate inputs and 11 memory elements per module. This includes the link circuits but not the central control circuitry, and provides for six memory registers per module, a number which has been found adequate for all programs written thus far. Since the number of modules should be at least of the order of several hundred, this adds up to thousands of memory elements and tens of thousands of gate inputs in the matrix alone.

These are alarming figures, and it would probably be difficult to find applications that would justify the cost involved if individual physical devices had to be employed for each element. However, it is conceivable that arrays of ferromagnetic cores could be used, and, furthermore, progress in the components field is such that it is reasonable to hope that within a few years we may have available manufacturing processes whereby entire blocks of logical circuitry could be constructed in one unit. Etching, plating, thin film components, multi-hole ferrite plates, and other techniques now in the development stage may be used to take advantage of the repetitive nature of the modules to sharply reduce the cost of the machine.

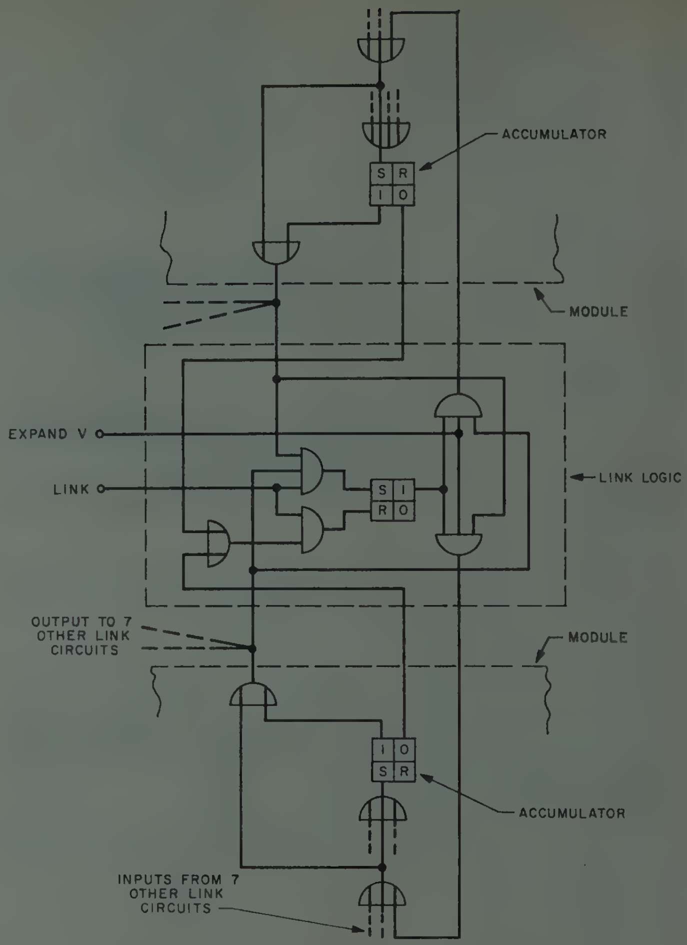


Fig. 11—Link circuit logic.

While we have specifically discussed a computer based on a rectangular matrix of modules using one-bit registers, it might be worthwhile to consider other arrangements. Possible variations include matrices in three or more dimensions, registers enlarged to handle multi-bit words, and polar coordinate arrays. Investigations of such variations have not yet been made and would probably occur naturally in conjunction with studies concerning applications of the machine.

A logical next step in the development of this computer would be to simulate it on a general purpose machine. Such a simulation (now being programmed on an IBM 704 at the Bell Laboratories) would be useful in testing complex programs and exploring possible applications.

## Acknowledgment

The idea of considering switching circuits in $n$-dimensions came to the author through the work of Professor D. A. Huffman of M.I.T. Thanks are due to C. Y. Lee and M. C. Paull of the Bell Telephone Laboratories for many interesting conversations which contributed directly and indirectly to the work presented here, and for their advice regarding the preparation of this report.

# Distribution of Leakage Flux Around a TWT-Focusing Magnet—A Graphic Analysis*

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**Summary**—Formulas and graphs are presented which describe the distribution of leakage flux around a tubular permanent magnet. The importance of this information derives from the fact that the external leakage flux from the magnets used for straight-field focusing of traveling wave tubes frequently interferes with the operation of other equipment in the vicinity.

It is noted that the decrease in field intensity with increased distance from the magnet is approximately exponential over the region of interest. The attenuation constant in the exponent is a function of the length-to-diameter ratio of the magnet. This relation is derived and reduced to a graph. This graph, and easily constructed auxiliary graphs, enable one to insert dimensional information about the magnet and to directly read out the relative field strength to be expected at various distances from the magnet.

Illustrations, based upon experience, demonstrate the usefulness of the graphs and their applicability to magnets which deviate from the tubular shape.

## I. INTRODUCTION

WHEN tubular permanent magnets are used for straight-field focusing of electron beams, the external magnetic leakage flux sometimes interferes with the operation of other equipment in the vicinity. This effect is particularly noticeable in the case of traveling wave tubes which employ long electron beams and require long focusing fields. In the design of shielding, or in the redesign or relocation of the magnet to minimize this interference, it is frequently useful to know what will be the distribution of flux around a given magnet configuration before the magnet is available for measurements.

In an earlier paper[1] the author has derived design equations and reduced them to graphic means for determining the dimensions of tubular magnets required to maintain specified values of field strength on the axis for specified gap geometries. Now the derivation is extended to include formulas for the distribution of external leakage flux when magnet dimensions and field strength are known. As in the earlier paper, the derived formulas are reduced to graphs so that the magnet designer may obtain the desired information directly from the graphs.

The utility of the graphic means presented in this and in the earlier paper is enhanced by the fact that optimum design of TWT circuits requires mutual adaptation of the electronic and magnetic requirements, and, in some cases, of the environmental requirements. Working out the details of this adaptation becomes very tedious if the effect of various adjustments of magnet geometry must be evaluated by individual calculations. It is expedited when the characteristics of contemplated magnet designs can be evaluated directly by reference to the graphs.

It has been observed that the flux through the median plane—the perpendicular plane intersecting the midpoint of the axis of the straight field permanent magnets—decreases with distance from the magnet, following very closely an exponential function of that distance. If $B_0$ is the flux density at the magnet surface, and $r_0$ is the radius of the cylindrical magnet, then the observed pattern of flux distribution in the median plane may be described by the equation

$$B = B_0 e^{\alpha(1-r/r_0)}. \tag{1}$$

The attenuation constant, $\alpha$, in the exponent has a derivable relation to the length-to-diameter ratio of the magnet. Since in air the field intensity in oersteds ($H$) is equal numerically to the flux density in gauss ($B$), one may also write

$$H = H_0 e^{\alpha(1-r/r_0)} \tag{2}$$

and may use the two expressions interchangeably. At the median plane the field intensity ($H_0$) on the surface of the magnet is essentially the same as that measured on the axis of the magnet.

The exponential function, which describes the decrease of flux density away from the surface of the magnet in the median plane, lends itself readily to the derivation of a formula which gives the field strength at any point in this plane as a function of the field strength and geometry of the magnet. It has been observed that the flux distribution outwardly from other parts of the magnet surface follows roughly the same pattern as that in the median plane. This may be seen in Fig. 1(a) which shows the typical distribution of flux density around a cylindrical magnet. So the formula which evaluates flux density at points in the median plane yields approximate values of the flux density at points equally distant from other parts of the magnet surface. For most purposes the closeness of this approximation is entirely adequate. The formula does not apply, of course, at points close to sharp corners on the magnet material which cause local concentration of flux.

In Section II the relation between the attenuation constant, $\alpha$, and the length-to-diameter ratio, $L/D$, is derived. In Fig. 2 this relation is displayed graphically for the range of conditions most likely to be encountered in the design of focusing magnets. It is probably evi-

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[1] M. S. Glass, "Straight field permanent magnets of minimum weight for TWT focusing—design and graphic aids in design," PROC. IRE. vol. 45, pp. 1100–1105; August, 1957.

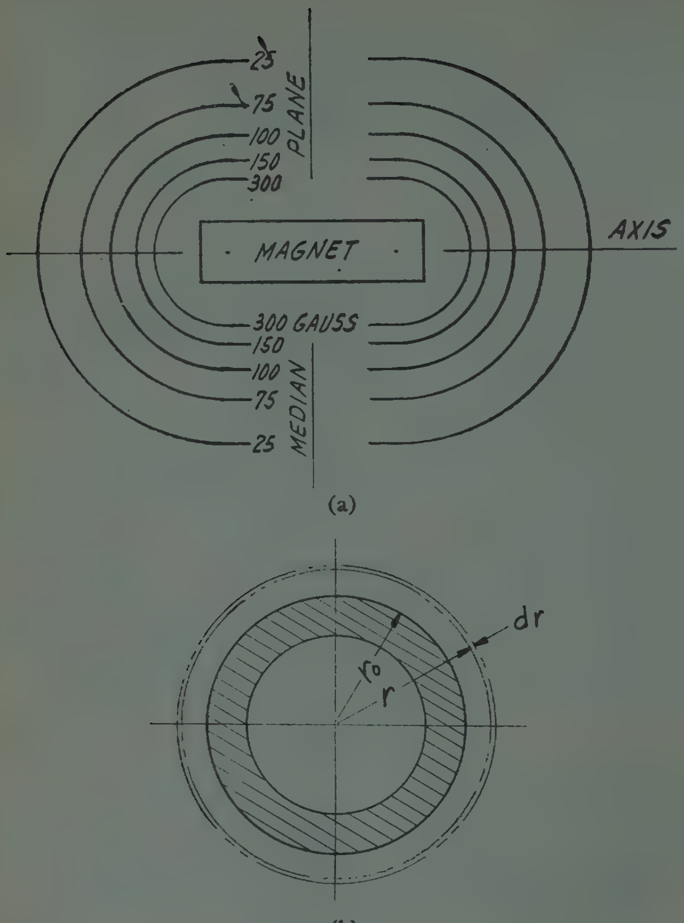

Fig. 1—(a) The distribution of field outwardly from the magnet in the median plane is quite similar to the distribution in other directions. (b) Section of tubular magnet. In the derivation this is assumed to be the section cut by the median plane.

dent to the reader that one may select the appropriate value of the attenuation constant, $\alpha$, from Fig. 2 and insert it in (1) to solve for the leakage flux density at a given distance from the magnet $(r-r_0)$, or to solve for the distance at which the field is attenuated to a specified level of flux desnity.

Repetitive calculations may be expedited, however, by the preparation of individual graphs on semi-log coordinates showing the field distribution for the representative magnet shapes indicated in Fig. 2. Such a graph is shown in Fig. 3 for the case of a tubular magnet in which an internal taper is used to obtain uniform distribution of field along the axis. In the use of this graph one may interpolate, if necessary, between the plotted values of $L/D$ and read out directly the relative field strength to be expected at a specified distance. One may also insert a value of field strength and read out the distance from the magnet at which this field strength will be found. To locate each line on this graph it was necessary only to solve (1) for a convenient point and draw a straight line through that point and the (1,1) point. This is illustrated in more detail in Section III.

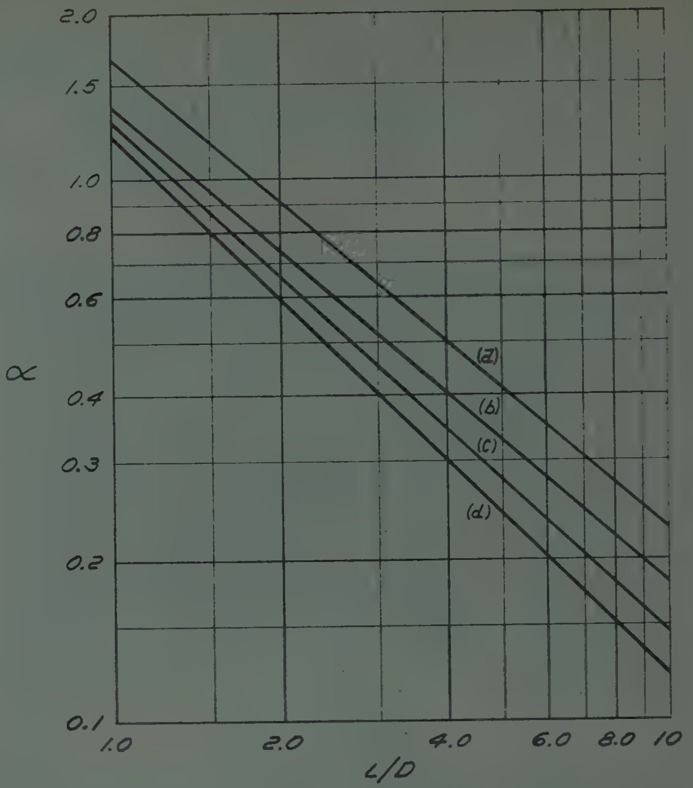

Fig. 2—Relation of the attenuation factor $\alpha$ to the length-to-diameter ratio of the tubular magnet for four representative conditions. (a) Magnet with external taper. (b) Magnet with internal taper. (c) Magnet with no taper ($U=10$). [$U=B/(-H)$ at the operating point of the magnet.] (d) Magnet with no taper ($U=5$).

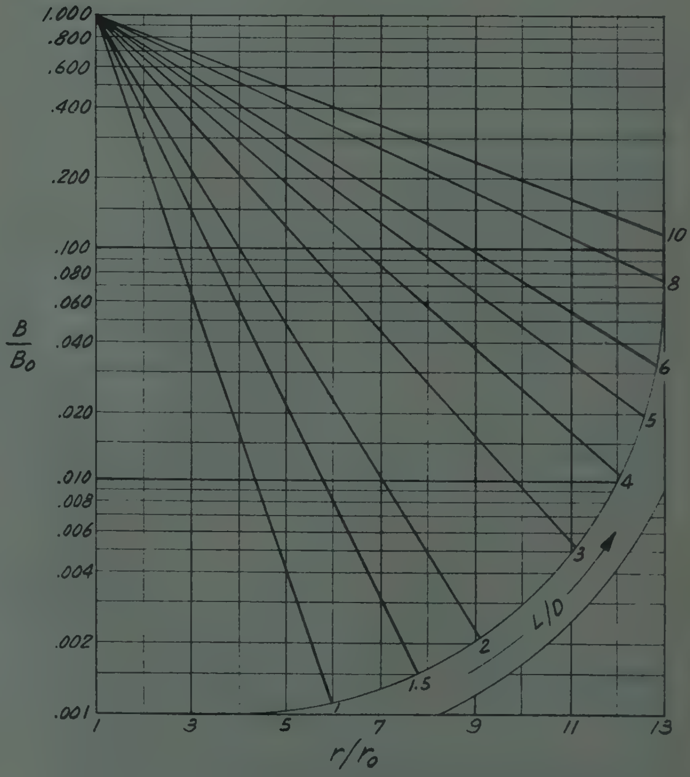

Fig. 3—Flux distribution—magnets with internal taper.

## II. DERIVATION OF $\alpha$, THE ATTENUATION CONSTANT

The relation between the geometry of the magnet and the term, $\alpha$, which appears in (1) and (2) may be established as follows:

1) Integrate the expression for flux distribution to find the total external flux through the median plane.
2) From this expression for total external flux derive an expression for external permeance.
3) Equate this expression for permeance to an expression based on magnet geometry. The resulting equation gives an evaluation of $\alpha$ in terms of magnet geometry.

In Fig. 1(b) the area of the annular segment is $2\pi r dr$. The flux through the annular segment is, from (1),

$$\text{Flux}_{\text{seg}} = B_0 e^{\alpha(r_0 - r)/r_0} 2\pi r dr. \tag{3}$$

The total flux passing through the median plane external to the magnet is obtained by integrating:

$$\text{Flux}_{\text{ext}} = 2\pi B_0 e^{\alpha} \int_{r_0}^{\infty} r e^{-\alpha r/r_0} dr.$$

This is an integral of the form:

$$\int x e^{ax} dx = \frac{e^{ax}}{a^2}(ax - 1).$$

So one may write

$$\text{Flux}_{\text{ext}} = \frac{r_0^2}{\alpha^2} 2\pi B_0 e^{\alpha} \Big[ - e^{-\alpha r/r_0}(\alpha r/r_0 + 1) \Big]_{r_0}^{\infty}$$

$$= 2\pi B_0(\alpha + 1) \frac{r_0^2}{\alpha^2}.$$

Since $H_0$ and $B_0$ are numerically the same in air, this may also be written

$$\text{Flux}_{\text{ext}} = 2\pi H_0(\alpha + 1) \frac{r_0^2}{\alpha^2}. \tag{4}$$

The external permeance is

$$P_{\text{ext}} = \frac{\text{Flux}_{\text{ext}}}{H_0 L} = \frac{2\pi}{L}(\alpha + 1)\frac{r_0^2}{\alpha^2}. \tag{5}$$

In the earlier paper[1] the external permeance of the cylindrical magnet was shown to be

$$P_{\text{ext}} = \pi F(N) \frac{r_0^2}{L} \tag{6}$$

in which

$$F(N) = \frac{1 - N/4\pi}{N/4\pi} \tag{7}$$

and $N/4\pi$ is the demagnetizing factor.[2] Equating the two expressions for external permeance gives

$$\frac{2\pi}{L}(\alpha + 1)\frac{r_0^2}{\alpha^2} = \frac{\pi}{L} F(N) r_0^2 \tag{8}$$

which reduces to

$$\frac{2}{\alpha^2} + \frac{2}{\alpha} - F(N) = 0. \tag{9}$$

For this quadratic equation there is the solution,

$$\frac{1}{\alpha} = \frac{-2 \pm \sqrt{4 + 8F(N)}}{4}.$$

The positive value of this solution reduces to

$$\alpha = \frac{2}{-1 + \sqrt{1 + 2F(N)}}. \tag{10}$$

The quantity $F(N)$ is a function of the demagnetizing factor, $N/4\pi$, which in turn is a function of the ratio $L/D$. So combining (7) and (10) with Bozorth-Chapin[2] data for the demagnetizing factor, one may obtain values of $\alpha$ to plot against $L/D$ in Fig. 2.

The first line (a) of Fig. 2 indicates values of $\alpha$ to be used for calculating distribution of field strength in the median plane of tubular magnets tapered externally to provide uniform focusing field along the axis. The external geometry of such magnets is sufficiently close to that of the prolate spheroid so that they should have nearly the same distribution of external flux. So in solving (10) for values of $\alpha$ for this line, one uses values of demagnetizing factor given by Bozorth and Chapin for the prolate spheroid (or, ellipsoid) magnetized along its major axis.

The second line (b) of Fig. 2 indicates values of $\alpha$ to be used for calculating distribution of field strength in the median plane of tubular magnets tapered internally to provide uniform focusing field along the axis. The uniform magnetization in these cases may be expected to give the same distribution of external field as that of a solid rod having very high permeability immersed in a magnetic field. For this case one uses the Bozorth-Chapin values of demagnetizing factor for $\mu = \infty$.

The third and fourth curves (c) and (d) of Fig. 2 indicate values of $\alpha$ to be used for calculating field strength distribution of tubular magnets with uniform cross section along their length. In beam-focusing applications these are generally magnets which are relatively short so that the field distribution on the axis is acceptably uniform without taper (for example, the case of a two-section magnet with a reversal of field between sections). To illustrate these cases one may use the Bozorth-

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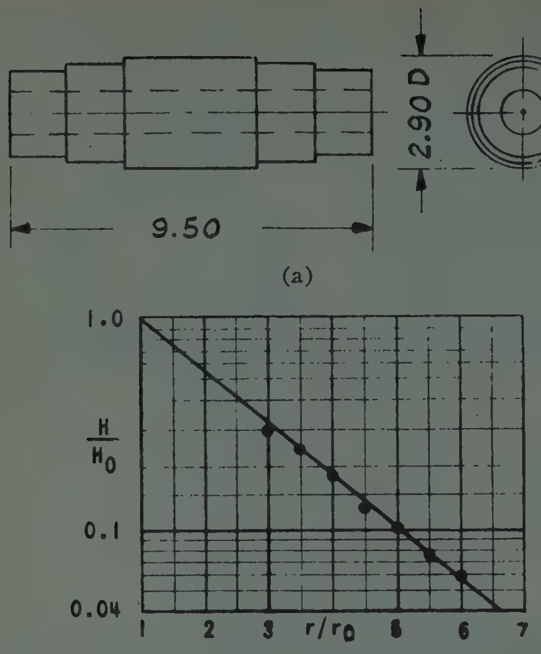
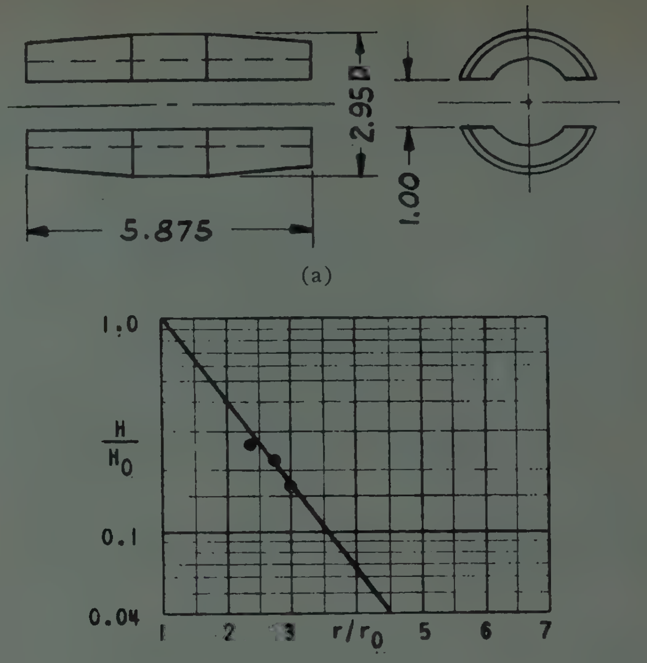
[2] R. M. Bozorth and D. M. Chapin, "Demagnetizing factors of rods," *J. Appl. Phys.*, vol. 13, pp. 320–326; May, 1942.



(a)

(b)

Fig. 4—(a) This magnet has the outer diameter reduced in steps to approximate an external taper. (b) The measured points fall closely on the line calculated for a magnet with external taper.



(a)

(b)

Fig. 5—(a) This externally tapered magnet has the sides cut away to accommodate transverse waveguides. (b) With the magnet so modified the measured points still confirm the calculated distribution.

Chapin data for $\mu=10$ and $\mu=5$. This describes the field distribution of permanent magnets operating at corresponding values of $U=B/-H$. These values represent operating points of certain magnets of high coercivity which might be so used.

## III. Application of the Graphs

The usefulness of the graphs has been demonstrated by laboratory tests in which field distributions calculated for existing magnets were checked satisfactorily against values of external field strength measured in the median plane. Accurate application of the graphs requires that the magnet shape be correctly classified under one of the types described in Fig. 2. The attenuation constant, $\alpha$, has different values depending upon whether the tubular magnet has internal taper, external taper, or no taper at all.

In the following discussion of representative cases there is excellent agreement between predicted values and measured values of field strength for each magnet which unmistakably resembles one of the basic shapes treated in the analysis. In some of the magnets selected for the tests the basic tubular design has been modified substantially to accommodate transverse waveguides and to facilitate packaging. Since these irregular shapes do not lend themselves readily to analysis, one may treat each of them as substantially equivalent to one of the shapes which have been analyzed. For example, a magnet of square section is treated as equivalent to a cylindrical magnet with diameter equal to one of the sides.

It will be noted in the analysis of Cases 4) and 5) that there is some uncertainty in the classification of these shapes with respect to the basic shapes. If this uncertainty is resolved incorrectly, the results will be correspondingly less accurate. However, in general these estimates of external field strength do not require a high order of accuracy, and thus the exercise of reasonable care in selecting the representative shape will result in acceptable estimates.

### *Case 1) A Tubular Magnet with External Taper*

The magnet selected for this test [Fig. 4(a)] is one in which the external diameter was reduced in two steps on either side of the median plane providing a reasonable approximation of a tubular magnet with external taper. This shape gives a nearly uniform distribution of field along the axis. The $L/D$ ratio for this magnet is 3.48. From Fig. 2, the corresponding value of $\alpha$ is 0.57 for a magnet with external taper.

One may now substitute the indicated value of $\alpha$ in (1) and solve for $B/B_0$ at some convenient value of $r/r_0$. One may then plot this solution on semi-log paper and draw a straight line through this point and the (1,1) point. This gives the field distribution to be expected in the median plane of the magnet [Fig. 4(b)]. It will be noted that the measured points fall quite closely on the calculated line.

### *Case 2) A Tubular Magnet with External Taper, Modified for Transverse Wave Guides*

The magnet used in this test [Fig. 5(a)] consists of two tapered pieces symmetrically placed with respect to the axis. In this arrangement they appear to be parts of a tubular magnet with externally tapered ends but with

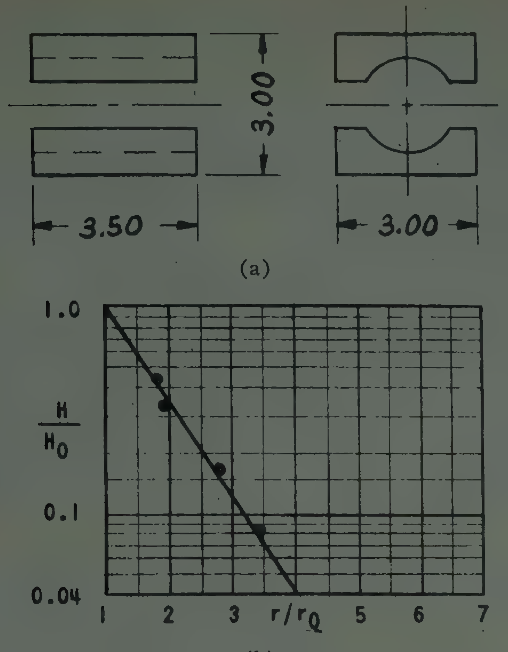


Fig. 6—(a) This pair of magnets is treated as a nontapered tubular magnet. (b) The measured points check well with the calculated curve.

portions of the wall removed to provide clearance for transverse waveguides. For purposes of graphic analysis one treats it simply as a tubular magnet with external taper. The $L/D$ ratio is 1.99 and the corresponding value of $\alpha$ is 0.92 for magnets with external taper. Solving (1) for this value of $\alpha$, one obtains the distribution characteristic shown in Fig. 5(b). The measured points again fall quite closely on the line, confirming the analysis for this magnet shape.

### *Case 3) A Short Tubular Magnet with No Taper*

The magnet selected for this test was a short one comprising two sections symmetrically disposed with respect to a common axis, and with spacing between to provide clearance for waveguides [Fig. 6(a)]. One reasons that this arrangement should be classified as a tubular magnet without taper. Measurements of field strength were made along a line perpendicular to the center of one of the large flat faces. In the analysis this magnet was treated as a tubular magnet with diameter equal to the spacing between the large flat faces.

The effective ratio of $L/D$ is seen to be 1.16. The corresponding value of $\alpha$ is 1.07 from Fig. 2 (the operating point is $U \cong 5$). Again one substitutes this value of $\alpha$ in (1) to obtain a point to plot. A line through this point and the (1,1) point is shown in Fig. 6(b). The measured points fall quite closely on the calculated line.

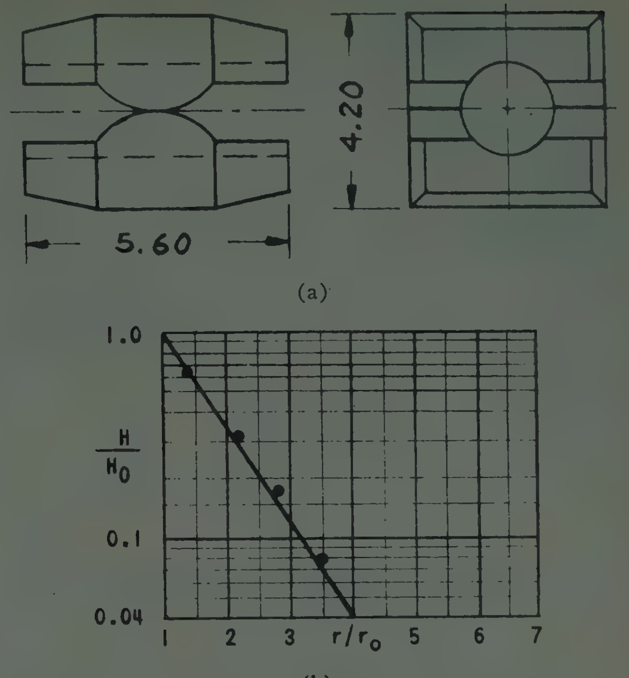


Fig. 7—(a) This irregularly shaped magnet has material removed internally to accommodate waveguides. The small external taper does not appreciably affect the distribution. (b) The measured points fall close to the line calculated for internal taper.

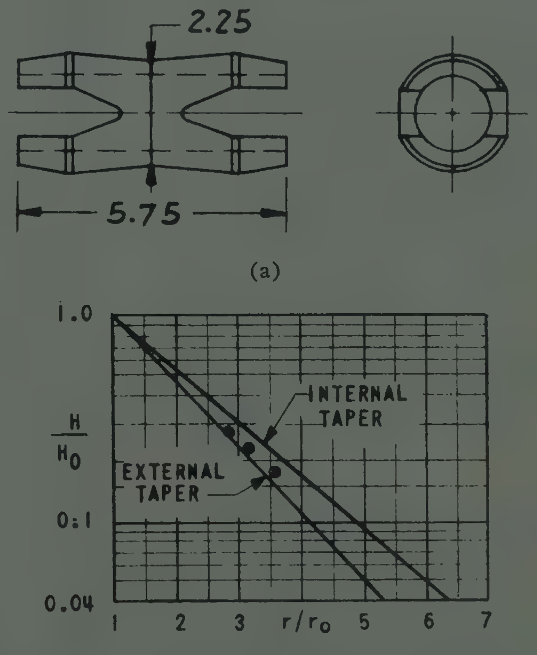


Fig. 8—(a) The irregularity of profile makes it uncertain whether to treat this magnet as having internal taper or external taper. The measurements indicate that either assumed distribution would generally give an acceptable approximation. (b) The measured points fall between the two calculated lines.

### *Case 4) A Magnet of Irregular Shape*

This magnet is an assembly of two bar magnets with median protuberances which act as separators so that the two portions are symmetrically placed with respect to the axis, [Fig. 7(a)]. The material removed on either side of the median protuberances to provide clearance for transverse waveguides is equivalent to a substantial internal taper. There is also a small external taper at the ends. The $L/D$ ratio is 1.33. For assumed internal taper,

$\alpha$ is 1.07.[8] It is seen in Fig. 7(b) that the measured results fall close to the line for $\alpha = 1.07$. So one finds in this case that the small external taper has negligible effect on field distribution.

### *Case 5) An Irregular Tubular Magnet*

The magnet shown in Fig. 8(a) is essentially tubular but somewhat irregular in shape. Clearance provided for transverse waveguides is equivalent to a substantial internal taper. There is also external taper at the ends. The $L/D$ ratio is 2.56. For assumed external taper, $\alpha$ is 0.74. For assumed internal taper, $\alpha$ is 0.6. Solving (1) for these values, one finds the two distribution characteristics shown in Fig. 8(b). The measured points fall between the two lines. The approximation represented by either assumed distribution would probably be acceptable in most cases.

## IV. ACKNOWLEDGEMENT

The author is indebted to E. D. Reed for helpful discussion of this paper.

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[8] It is merely coincidence that $\alpha$ has the same value in Cases 3) and 4).

# Correspondence

## A Low-Noise Electron-Beam Parametric Amplifier*

Several electron tubes employing fast-wave parametric amplification have been built and tested. These tubes are designed to operate in the 500 mc region. They exhibit a number of unusual properties. Noise temperatures in the liquid nitrogen range have been measured. The tubes are completely unilateral and unconditionally stable. The present tubes have bandwidths of about 10 per cent. Inherently such tubes are capable of much greater bandwidth since the amplifying process appears not to limit the bandwidth at all. The bandwidth for a given tube is determined substantially by its input and output couplers.

The principles of operation include concepts explained in a previous letter[1] which reported on a suggestion made earlier, that low noise figures might be obtained by parametrically amplifying the fast wave on an electron beam. A device of this kind is shown diagrammatically in Fig. 1. The letter further proposed the use of Cuccia electron couplers[2] for coupling the signal input and output circuits to a fast wave of the type which involves transverse electron motion in a uniform magnetic field; pumping by means of a nonhomogeneous transverse field was also suggested. In the present letter we report the results of work in continuation of those ideas. We describe a new electrode structure which provides efficient parametric amplification for this type of fast wave, and report experimental data.

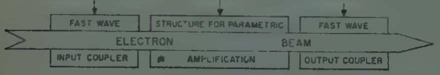

Fig. 1—Diagram of a fast-wave parametric amplifier.

In this type of tube, an electron gun produces a beam which flows parallel to the flux lines of a uniform magnetic field. The magnetic field intensity is so chosen that the cyclotron frequency is approximately equal to the frequency of the signal to be amplified. The input and output couplers are of the Cuccia type, described in detail in the papers mentioned above.[1,2] Parametric amplification is accomplished by a quadrupole electrode structure to which is applied a pumping signal whose frequency is twice the cyclotron frequency. The tube derives its name from this structure and is called a quadrupole amplifier.

The input electron coupler serves two important functions. It extracts the fast wave component of the beam noise while simultaneously creating a new fast wave in accordance with the signal. Ideally, if we start with a signal on the input coupler and fast-wave noise on the beam, as the beam flows through the coupler the signal is completely transferred to the beam and the noise is completely stripped from it. In none of our tubes as yet has the transfer process been made to work perfectly. The degree to which it can be made to work plays an important part in determining the noise figure of the tube.

If there were only a drift region between the input and output couplers, all electrons in traversing that region would follow helical paths of constant radius. The purpose of the quadrupole structure is to provide means for increasing the radii of the helical paths. The factor by which the radii are increased is a measure of the gain of the tube.

The quadrupole structure and how it is pumped is illustrated in Fig. 2, which shows a cross section representing the electrode configuration. Assume that the beam flow is into the paper and that the sense of the helical electron motion is clockwise. The polarities indicated in the figure correspond to an instant when the top and bottom electrodes are positive and when the left and right electrodes are negative. The horizontal and vertical arrows show the forces exerted upon electrons in the four corresponding regions. We see that the electron on the top left, shown solid, encounters a force which accelerates it along its clockwise path. The other electron, shown on the top right as an empty circle, is subjected to a force which decelerates its orbital motion. Note that there is no field at all at the center and that the field intensity increases linearly with distance from the center. Thus the forces exerted upon an orbiting electron are proportional to the radius of the circle in which it moves, so that the radius must increase or decrease exponentially.

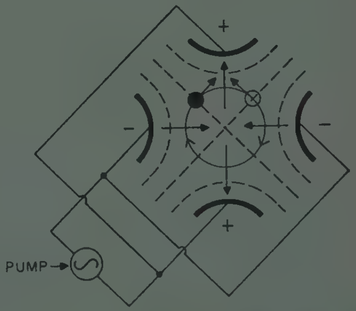

Fig. 2—Cross section of the quadrupole pumping structure illustrating the forces exerted upon electrons (arrows), and the equipotential planes (dashed lines).

The circle in which an electron moves would be very small with a weak signal. One might wonder what happens when the circle is off-center. Analysis shows that this does not matter; the exponential increase or decrease of the radius depends only on how nonhomogeneous the electric field is.

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* Received by the IRE, July 28, 1958. Presented at the Conference on Electron Tube Research, Quebec, Can., June, 1958.

[1] R. Adler, "Parametric amplification of the fast electron wave," PROC. IRE, vol. 46, pp. 1300–1301; June, 1958.

[2] C. L. Cuccia, "The electron coupler," *RCA Rev.*, vol. 10, pp. 270–303; June, 1949.

The rate of growth for the two extreme cases of best and worst phase (corresponding, respectively, to the accelerated and decelerated electrons of Fig. 2) is given by

$$\rho = \rho_0 e^{\pm(k/B)t}$$

where

$\rho$ = radius of helical electron path

$B$ = magnetic flux densitv

$$k = \frac{1}{2}\sqrt{\left(\frac{\partial}{\partial x}\right)^2 + \left(\frac{\partial}{\partial y}\right)^2}\ \frac{\partial V}{\partial x}$$

$V$ = electric potential in the quadrupole region

Fig. 3 shows the curved surfaces generated by the motion of electrons with best and worst phase. Both enter from the left along the same cylindrical surface; one radius becomes very large and the other negligibly small.

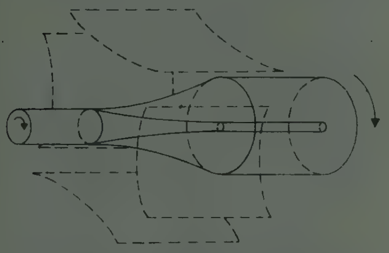

Fig. 3—Surfaces generated by the motion of electrons with best and worst phase for amplification.

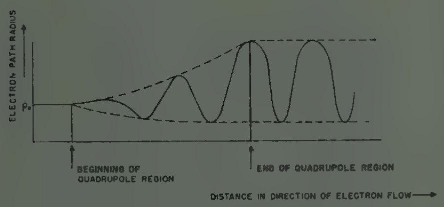

Fig. 4—Electron path radius as a function of distance for a particular instant of time.

For an input signal which is accurately synchronized with one-half the pump frequency, a specific phase condition will be maintained, for instance that of maximum gain. If the signal frequency is then changed slightly, conditions of maximum gain and maximum loss occur alternately. This is shown in Fig. 4. On the average, the resulting output signal is larger than the input signal because the exponential growth always outweighs the exponential drop. The output signal contains a beat with round tops and sharply pointed dips; it consists of two sine wave components, one at the signal frequency, the other at the familiar idler frequency, the difference between pump and signal frequencies. For unity input signal amplitude, the amplitudes of the two components are, respectively, cosh $(k/B)t$ and sinh $(k/B)t$. When the gain is made large, both components approach $\frac{1}{2}$ exp $(k/B)t$.

Note that we obtained this wave form by altering the signal frequency. The pump frequency and the magnetic field were not changed. Gain resulted from averaging over many electrons entering with every possible phase. This mechanism remains the same regardless of signal frequency. Thus the amplifying process does not limit the bandwidth at all. By using different couplers, we may produce fast or slow electron waves at any signal frequency; the individual electrons which make up these waves must still orbit at the cyclotron frequency and we can amplify their motion by pumping at twice that frequency. The bandwidth of the tube is therefore determined only by the couplers.

Fig. 5 illustrates the tubes with which we have made our most interesting experiments. For these, the signal frequency is about half the pump frequency. The figure shows the three main sections schematically. Input and output couplers are tuned by built-in coils. The quadrupole structure is tuned by four coils and is strapped to insure operation in a $\pi$ mode.

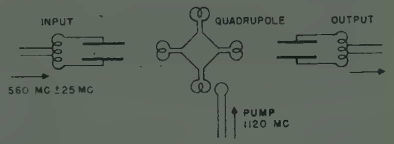

Fig. 5—Schematic diagram of the experimental quadrupole amplifier.

A very low beam voltage is used in order to get a reasonable number of cyclotron orbits in a short tube. At six volts there are four orbits per centimeter for the magnetic field of 200 gauss. The pencil beam is emitted from a cathode surface of very small diameter and is focused so as to approximate Brillouin flow. The beam carries 35 microamperes with a current density corresponding to about 60 per cent of the theoretical value for Brillouin flow. The quadrupole section is one centimeter long. The gain depends upon how hard we pump. It is easy to get more than 20 db gain with a few milliwatts of pump power. At first thought a gain of 20 db per cm may seem high, but it should be noted that the beam flows in only one direction and there is no other link between input and output; therefore, the tube is unconditionally stable.

The best reliable noise figure measurement so far was made on our most recent tube. The noise figure was 1.3 db, of which about 0.4 db represented input coupler loss. The noise figure was measured with a broadband noise source which excited both signal and idler. To obtain this performance it was essential to match accurately at the input for both signal and idler frequencies.

Why is the noise figure not zero db? The excess noise appears to come from beam irregularities, secondary electrons and other not very fundamental phenomena. The first tube tested had a noise figure of about 3 db. The latest tube, in which more care had been taken in the electron gun to minimize beam irregularities, has the much lower noise figure cited above. Probably this is not the best that can be done.

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## A Proposed Technique for the Improvement of Range Determination with Noise Radar*

In a recent communication,[1] Bourret describes a method by which he proposes to improve the range accuracy of a radar. This is to be accomplished in general (although Bourret considers only a special case) by choosing a transmitted signal which has an autocorrelation function, some derivative of which, say the $m$th, has a delta function at the origin and nowhere else. Then, as Bourret shows in his special case, a delta function will appear in the *signal* component of the cross correlation function of the $m$th derivative of the transmitted signal and the receiver input waveform, at a delay corresponding to the true target range. The implication is that, because of the appearance of this delta function, the target range can be ascertained with any degree of accuracy required.

The value of this scheme becomes suspect immediately when one considers the following simple heuristic argument. As Bourret notes, when white noise is present, all range information is contained in the cross correlation function of the undifferentiated transmitted signal and the receiver input waveform, and this information is insufficient to give range unequivocally. Therefore one should not expect to find a method which will eliminate this inherent equivocation in range. The fallacy of Bourret's argument lies in his failure to consider the effect of his processing scheme on the noise component of the received waveform. It is the purpose of this comment to show that the presence of a delta function in the processed signal component, as required by Bourret, implies that the processed noise component will have an infinite average power which will effectively obscure the position of the signal component delta-function peak.

We denote the transmitted (finite-energy) waveform by $f(t)$. Its autocorrelation function is

$$R(\tau) = \int f(t)f(t-\tau)dt \qquad (1)$$

where the integration is over all regions of nonzero integrand. The $m$th derivative of $R$ with respect to $\tau$ is

$$R^{(m)}(\tau) = (-1)^m \int f(t)f^{(m)}(t-\tau)dt. \qquad (2)$$

We postulate that there is some smallest value of $m$, say $m_1$, for which there is a delta function in $R^{(m)}(\tau)$ at $\tau=0$ and nowhere else. [An $f(t)$ which has a spectrum which is a rational function of frequency will satisfy this postulate.] Using the fact that $R$ is an even function of $\tau$, it is easily shown that $m_1$ must be even.

We assume a received waveform of the form $f(t-\tau_0)+n(t)$ where $\tau_0$ is the true target delay and $n(t)$ is a stationary, white noise waveform with (double-ended) spectral density $N_0/2$ (watts/cps). Following Bourret, we crosscorrelate this received

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[1] R. Bourret, "A proposed technique for the improvement of range determination with noise radar," Proc. IRE, vol. 45, p. 1744; December, 1957.

waveform with the $m_1$th derivative of the transmitted signal:

$$C(\tau) = \int [f(t-\tau_0) + n(t)] f^{(m_1)}(t-\tau)dt$$
$$= (-1)^{m_1} R^{(m_1)}(\tau-\tau_0) + \int n(t) f^{(m_1)}(t-\tau)dt. \tag{3}$$

The signal component of $C(\tau)$, that is, $R^{(m_1)}(\tau-\tau_0)$, has a delta function at $\tau=\tau_0$. The average power of the noise component of $C(\tau)$ is given by

$$N_{\text{av}} = \overline{\left[\int n(t) f^{(m_1)}(t-\tau)dt\right]^2}$$
$$= \iint \overline{n(t)n(s)} f^{(m_1)}(t-\tau) f^{(m_1)}(s-\tau) ds dt. \tag{4}$$

From the assumption that the noise is white and stationary, it follows that

$$\overline{n(t)n(s)} = \frac{N_0}{2}\delta(t-s), \tag{5}$$

so (4) becomes

$$N_{\text{av}} = \frac{N_0}{2}\int [f^{(m_1)}(t-\tau)]^2 dt$$
$$= \frac{N_0}{2} R^{(2m_1)}(0). \tag{6}$$

By invoking the properties of singularity functions[2] and the fact that $m_1$ is even, it can be shown that since $R^{(m_1)}(0)$ is infinite, then $R^{(2m_1)}(0)$ is also infinite. Thus, the average noise power, as well as the peak signal power, is infinite.

A further insight is gained by looking at the problem from the linear filtering, rather than the correlation, point of view. One may interpret the first equality in (3) as giving $C(\tau)$ as the output of a linear filter whose impulse response is $f^{(m_1)}(-t)$ and whose input is the received waveform. If the Fourier transform of $f(t)$ is $F(\nu)$, where $\nu$ is in cps, then the transfer function of this filter is $(-j2\pi\nu)^{m_1}F^*(\nu)$, where the asterisk denotes "complex conjugate." Now, the voltage-density spectrum of the signal component at the filter input is $F(\nu)e^{-j2\pi\nu\tau_0}$; thus the signal component at the filter output has the spectrum

$$(-j2\pi\nu)^{m_1}|F(\nu)|^2 e^{-j2\pi\nu\tau_0}.$$

This latter spectrum is of course the Fourier transform of $(-1)^{m_1}R^{(m_1)}(\tau-\tau_0)$, the signal component of (3), and because of the delta function in this signal component at $\tau=\tau_0$, we have the following limit:

$$\lim_{|\nu|\to\infty} (-j2\pi\nu)^{m_1}|F(\nu)|^2 = A \tag{7}$$

where $A$ is some real constant. Further, we see that the noise power-density spectrum at the filter output is

$$(2\pi\nu)^{2m_1}|F(\nu)|^2\frac{N_0}{2},$$

and it follows from (7) that as $|\nu|\to\infty$

$$(2\pi\nu)^{2m_1}|F(\nu)|^2\frac{N_0}{2} \to \frac{AN_0}{2}(j2\pi\nu)m_1. \tag{8}$$

Note from (7) and (8) the significant difference in the behavior of the filter output signal and noise spectra for large $|\nu|$: the former spectrum approaches a finite constant, while the latter becomes indefinitely large.

Now, the height of the peak at $\tau=\tau_0$ of the signal component of the filter output is the area under the output-signal (voltage-density) spectrum with the delay factor removed; also, the average output noise power is the area under the output noise power-density spectrum. We may reasonably take the ratio of the square of the first area to the second area (*i.e.*, the peak-signal to noise *power* ratio) as a measure of the ability to determine the position of the signal peak in the noise background. By evaluating this ratio first with finite limits, $\pm\Delta$, on the area integrals, and then letting $\Delta\to\infty$ in the resulting expression, one can easily show, using (7) and (8) and the fact that $m_1$ is even, that the peak signal to noise ratio at the output of Bourret's device is zero. Thus, the signal peak will not "stand out" and mark the true range unequivocally as Bourret implies; the noise will mask the signal peak.

It is well known, in fact, that the linear filter which maximizes the peak signal to noise power ratio (and, it would seem, the range accuracy) is a matched filter, *i.e.*, one whose impulse response is just $f(-t)$.[3] [Note from (3) with $m_1=0$ that the signal component of the matched-filter output is just $R(\tau-\tau_0)$, which is what is required in the Woodward-Davies theory.[4]] The transfer function of the matched filter is $F^*(\nu)$, the conjugate of the signal spectrum. We see from (7), on the other hand, that the transfer function of Bourret's filter is asymptotically the *inverse* (*i.e.*, the reciprocal) of the signal spectrum, which is very far from optimum.

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[2] E. A. Guillemin, "Mathematics of Circuit Analysis," John Wiley and Sons, Inc., New York, N. Y., pp. 531–547; 1949.

[3] J. H. Van Vleck and D. Middleton, "A theoretical comparison of the visual, aural and meter reception of pulsed signals in the presence of noise," *J. Appl. Phys.*, vol. 17, pp. 940–971; November, 1946.

[4] P. M. Woodward, "Probability and Information Theory, with Applications to Radar," McGraw-Hill Book Co., Inc., New York, N. Y.; 1953.

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## WWV Standard Frequency Transmissions*

Since October 9, 1957, the National Bureau of Standards radio stations WWV and WWVH have been maintained as constant as possible with respect to atomic frequency standards maintained and operated by the Boulder Laboratories, National Bureau of Standards. On October 9, 1957, the USA Frequency Standard was 1.4 parts in $10^9$ high with respect to the frequency derived from the UT 2 second (provisional value) as determined by the U. S. Naval Observatory. The atomic frequency standards remain constant and are known to be constant to 1 part in $10^9$ or better. The broadcast frequency can be further corrected with respect to the USA Frequency Standard as indicated in the table below. This correction is *not* with respect to the current value of frequency based on UT 2. A minus sign indicates that the broadcast frequency was low.

The WWV and WWVH time signals are synchronized; however, they may gradually depart from UT 2 (mean solar time corrected for polar variation and annual fluctuation in the rotation of the earth). Corrections are determined and published by the U. S. Naval Observatory.

WWV and WWVH time signals are maintained in close agreement with UT 2 by making step adjustments in time of precisely plus or minus 20 msec on Wednesdays at 1900 UT when necessary; step adjustments were made at WWV and WWVH on July 2 and July 16, 1958.

WWV FREQUENCY†

| July, 1958 1500 UT | Parts in $10^9$ |
|---|---|
| 1 | −3.3 |
| 2 | −3.3 |
| 3 | −3.4 |
| 4 | −3.3 |
| 5 | −3.3 |
| 6 | −3.3 |
| 7 | −3.2 |
| 8 | −3.3 |
| 9 | −3.3 |
| 10 | −3.3 |
| 11 | −3.3 |
| 12 | −3.4 |
| 13 | −3.4 |
| 14 | −3.5 |
| 15 | −3.5 |
| 16 | −3.6 |
| 17 | −3.5 |
| 18 | −3.5 |
| 19 | −3.5 |
| 20 | −3.5 |
| 21 | −3.4 |
| 22 | −3.4 |
| 23 | −3.3 |
| 24 | −3.3 |
| 25 | −3.2 |
| 26 | −3.2 |
| 27 | −3.2 |
| 28 | −3.2 |
| 29 | −3.1 |
| 30 | −3.1 |
| 31 | −3.0 |

† WWVH frequency is synchronized with that of WWV.

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* Received by the IRE, August 15, 1958.

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## A Further Note on Differentiability of Autocorrelation Functions*

Naturally I was quite interested in Beutler's recent note[1] on this subject; apparently it was prompted by some of my previous remarks.[2] However, Beutler and

* Received by the IRE, January 27, 1958.

[1] F. J. Beutler, Proc. IRE, vol. 45, p. 1740; December, 1957.

[2] D. G. Brennan, "Smooth random functions need not have smooth correlation functions," Proc. IRE, vol. 45, pp. 1016–1017; July, 1957.

I were talking about somewhat different things, differing to a greater extent than Beutler may have realized, and certain comments and questions I have received indicate that it may be desirable to clarify this difference. Equations below will be numbered from (8) onwards, and (1)–(7) will refer to those in the original note.[2]

To begin with, Beutler says[1] that I gave "... conditions under which an autocorrelation function of a stationary process is differentiable at the origin." I should like to emphasize that "stationary process" is Beutler's language, not mine. Beutler was thinking in terms of the stochastic processes studied by mathematicians; however, there is not the faintest hint or suggestion of such ensembles to be found anywhere in the development of the previous note. Indeed, the preliminary manuscript (which was not without misleading language of its own) explicitly included the sentence: "We are not concerned with probability-theoretic results on ensembles, whether ergodic or not." In the interests of space this sentence was omitted from the version submitted for publication. However, I am sorry if this particular deletion misled anyone. The note[2] was concerned only with those ordinary (real-valued, measurable) functions of a real variable for which the limits (1) and (2) exist, and are otherwise arbitrary, except for the conditions explicitly imposed as needed. The word "stationary" was used nowhere; indeed, I do not even know what "stationary" really means for such functions.

The reason for this avoidance of ensembles in the original note[2] is that in physical applications such as Fig. 1 of the same note, the behavior of the autocorrelation function, and hence any physical datum derived therefrom, depends only on the particular function from which it is computed and not on some imaginary ensemble of sample functions. As I have observed on other occasions concerning one such application, we have only one ionosphere, not a basketful of them. This is not to suggest that all physical applications are of this type, but many turn out this way when closely studied. The analytical point of view employed in the note is essentially that of footnote 3 in the same note; this should be read by anyone who is under the impression that autocorrelation functions are necessarily related to ensembles. There is a long record of applications to physics and engineering from essentially this point of view, going back at least to 1920, when Taylor[3] wrote a classical paper that stimulated much of the subsequent work of this type, but which also contributed somewhat (through no fault of Taylor's) to the "folk theorem" mentioned in the original note. (This last remark does not in any way minimize the considerable importance of Taylor's results, but certain of these require more stringent conditions for their validity than has sometimes been thought.) Apart from certain differences in the formal definitions involved, I suspect that the note by Bourret[4] in the same issue as Beutler's note[1] also represents essentially this view; at least, I do not know how to construct a radar transmitter that transmits an infinite ensemble of distinct functions.

Returning to Beutler's note,[1] the last paragraph of this suggests that his sentence "differentiability ... is assured under conditions much weaker than the above" should have read "... weaker than 2) and 3) above," or something similar. However, it is also possible to formulate 1) in terms of a Lipschitz condition in quadratic mean. Furthermore, all three conditions may be stated in terms of mean-square "time" averages (or "space" averages); there is no need to introduce the ensemble averages or the ergodic hypothesis used by Beutler. We again use $\langle\ \rangle$ as in the original note,[2] and let us say that $f(t)$ satisfies a mean-square Lipschitz condition of order $p$ if there is a number $M$ such that for $|\tau| \leq 1$,

$$(\langle[f(t+\tau)-f(t)]^2\rangle)^{1/2} \leq |\tau|^p M. \quad (8)$$

We say that $f(t)$ is mean-square differentiable if there is a function $f_s'(t)$ such that

$$\lim_{\tau\to 0} \left\langle\left[\frac{f(t+\tau)-f(t)}{\tau} - f_s'(t)\right]^2\right\rangle = 0. \quad (9)$$

Then "uniform" and "uniformly" in the conditions 1)–3) of the first note may be replaced throughout by "mean-square." The proofs follow from (6) and (7) exactly as before.

The reason why I did not state these mean-square conditions explicitly in the first note was that I did not think they were particularly meaningful with respect to engineering and physics. For myself, at any rate, I do not have much feeling for what a function with a mean-square derivative $f_s'$ "looks" like. It is not particularly a problem to state arbitrarily sharp "conditions," if one is not fussy about how meaningful they are; *e.g.*, the condition: $\rho'(0)$ exists if and only if

$$\langle[f(t+\tau)-f(t)]^2\rangle = o(\tau) \quad (10)$$

[this is a trivial consequence of (6) and evidently cannot be sharpened at all]. One of the objectives in the original paper was to state "local" conditions (analogous to continuity) which, when "globally" applied, would be sufficient to guarantee the existence of $\rho'(0)$. As was essentially indicated in the first note, the conditions 2) and 3) were not completely satisfactory in this respect, but it is my feeling that they are more illuminating for engineering purposes than the mean-square conditions above. It was quite clear from (6) and (7) that the uniformity requirements could be relaxed in various directions; however, it is less clear that (8) and (9) are appropriate directions for the purposes of the present journal.

These observations are not intended to suggest that the facts quoted by Beutler are of no mathematical interest; any mathematician, including the present writer, would agree that they are of such interest.

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[3] G. I. Taylor, "Diffusion by continuous movements," *Proc. Math. Soc. (London)*, series 2, vol. 20, pp. 196–212; 1921–1922.

[4] Richard Bourret, "A proposed technique for the improvement of range determination with noise radar," Proc. IRE, vol. 45, p. 1744; December, 1957.

## *Author's Comments*[5]

This writer regrets the apparent misunderstanding arising from the notes of Brennan[2,6] and the undersigned.[1] It is hoped that the following remarks will help to clarify matters.

The autocorrelation function defined by Brennan's (1) differs from the definitions customarily used.[7,8] The two definitions coincide when (and only when) the random process in question is stationary and ergodic. It is now evident that this divergence of meanings is responsible for the discrepancies in the results of Brennan and the undersigned.

We recall that the textbook definition of the autocorrelation is given as follows:[1] let $p(x_1, t_1; x_2, t_2)dx_1dx_2$ be the probability that $f(t)$ lies between $x_1$ and $x_1+dx_1$ at time $t_1$, and between $x_2$ and $x_2+dx_2$ at time $t_2$. Then the autocorrelation $r(t_1, t_2)$ is

$$r(t_1, t_2) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1x_2p(x_1, t_1; x_2, t_2)dx_1dx_2. \quad (11)$$

If $p$ depends only on the difference between $t_1$ and $t_2$, we call the process stationary, and write the correlation $r(\tau)$ in terms of the single variable $\tau = t_2 - t_1$. Finally, the process is ergodic if time and ensemble averages are equal, that is

$$r(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{+T} f(t+\tau)f(t)dt. \quad (12)$$

It is the latter form which Brennan calls $\rho(\tau)$ and defines as autocorrelation for all processes, stationary and ergodic or not.

Brennan's function $\rho(\tau)$ possesses properties considerably different from those of the usual autocorrelation. For example, let $f(t)$ be a (nonstationary) process which becomes zero or approaches zero for large $|t|$. Then $\rho(\tau)=0$ for every $\tau$.

On the other hand, the $\rho(\tau)$ of a Brownian motion[9] or diffusion process diverges to infinity for every $\tau$. The differentiability properties of $\rho(\tau)$ also differ from those of the autocorrelation function; in particular, an autocorrelation function need not be differentiable when Brennan's (4), (8), and (10) are satisfied.[2,6]

Finally, the undersigned wishes to comment on Brennan's inference[6] that ensemble properties are not appropriate when a process has only a limited number of realizations. Since we cannot know in advance which realization will occur, all possible ensemble members must be taken into account in

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[5] Received by the IRE, February 7, 1958.

[6] D. G. Brennan, "A further note on differentiability of autocorrelation functions," this issue, p. 1758.

[7] Laning and Battin, "Random Processes in Automatic Control," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 96–99; 1956.

[8] H. S. Tsien, "Engineering Cybernetics," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 113–114; 1954.

[9] If we start with $f(0)=0$, both time and ensemble averages of $f(t)f(t+\tau)$ are given asymptotically by min $(t, t+\tau)$. Substituting this expression into (2) yields the stated result. For a description of the Brownian motion and diffusion processes, see M. C. Wang and G. E. Uhlenbeck, "On the theory of the Brownian motion," *Phys. Rev.*, vol. 36, pp. 823–841; September, 1930. The same results are achieved rigorously by J. L. Doob in "The Brownian movement and stochastic equations," *Ann. Math.*, vol. 43, pp 351–369; April, 1942.

specifying or predicting average characteristics. Both theoretical and practical implications are involved in this statement. In the first place, the evolution of the theory of stochastic processes[10] has been concerned with ensembles almost exclusively; hence, the engineer has available a large body of theory when he deals with random phenomena from an ensemble viewpoint. On the practical side, a sequence or ensemble of experiments is often used to predict and specify future average performance. For example, a number of missiles are launched to determine the distribution of target misses; a series (ensemble) of gyro drift tests are conducted to predict system behavior when such a gyro is used; a radar tracking experiment is performed again and again, possibly under widely varying weather conditions. The latter example illustrates a particular point of interest; a radar tracking performance time average obtained in one type of weather is not representative if all types of weather are to be considered. That is, the ensemble average rather than the time average must be used if results are to be meaningful.[11]

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[10] The most complete and rigorous exposition of the theory is given by J. L. Doob, "Stochastic Processes," John Wiley and Sons, Inc., New York, N. Y.; 1953.

[11] If each day's radar tracking trial is thought of as a separate realization in the ensemble, the process (consisting of all members of the ensemble) is nonergodic.

### *Letter from Mr. Brennan*[12]

I am afraid that some of the remarks in Beutler's letter cannot pass unnoticed. I have shown this correspondence to one of my colleagues who is much better qualified than I to comment on certain aspects of Beutler's letter, and who has kindly set forth some of his comments in an accompanying note. The nature and extent of his qualifications can be partially estimated from the fact that the "Brownian motion" process as studied by Doob, to which Beutler refers, is quite generally known in the contemporary mathematical literature of the subject as the Wiener process. Some examples,[13–17] are given here.

I should also like to comment on three specific points. First, I have not surveyed the whole of the literature of mathematics, engineering, and physics, and so I should be reluctant to say that "autocorrelation function" is not the term customarily used for Beutler's function $r(t_1, t_2)$. I do know, however, that this function, or essentially this function, is often called a covariance function. For example, it is so designated in the book by Doob cited in Beutler's note above, and also in the book by Loève cited in Beutler's note of last December. This fact must be known to Beutler, as the results he quoted from Loève in his December note are stated by Loève in the "covariance" terminology. Beutler had to choose the source of his "textbook definition" with some care. Also, his December note includes the sentence: "The autocorrelation $\rho(\tau)$ of $f$ is defined in terms of this time average," and the relation of this sentence to his present discussion is not entirely clear. It is true that some writers use the term "autocorrelation" for either type of function; this fact is to be regretted, if for no other reason than that it may be partly responsible for the present tempest in a teapot. In any event, the definition I used: 1) was the appropriate definition for the problems to which the note was addressed, and 2) was stated as plainly as could possibly be imagined in the very first sentence of the note. In what follows, I shall speak of Beutler's $r(\tau)$ as a covariance function and my $\rho(\tau)$ as a correlation function.

Second, Beutler states (charitably understood) that a covariance function need not be differentiable when my (4), (8), and (10) are satisfied. Now, one is often interested in problems involving the correlation function $\rho(\tau)$ of some function $f(t)$ under circumstances when no stochastic process whatever is under consideration, and hence under circumstances when no covariance function whatever is presenting itself to be differentiated. My note was concerned with circumstances of this type, though Beutler has evidently not yet assimilated this fact. (*Cf.* his " . . . defines as autocorrelation for all *processes*, . . . ") In the first instance, therefore, his statement has no meaning whatever. However, my (4), (8), and (10) (and others) imply the differentiability of a covariance function in exactly the same sense and under exactly the same circumstances as those envisaged in Beutler's December note—namely, when the function in question happens to be a sample function of an ergodic stochastic process. Furthermore, it is a trivial matter to see that the obvious analog to (6) for a strictly stationary stochastic process $x(t)$, namely

$$r(0) - r(\tau) = \tfrac{1}{2}E\{[x(t+\tau) - x(t)]^2\}, \quad (11)$$

[this is much easier to establish than (6) itself], implies that the equally obvious analog to (10),

$$E\{[x(t+\tau) - x(t)]^2\} = o(\tau), \quad (12)$$

furnishes a necessary and sufficient condition that the covariance function $r(\tau)$ of a strictly stationary stochastic process shall be differentiable at $\tau = 0$. If Beutler wishes to repudiate altogether the claim in his December note that "differentiability . . . is assured under conditions much weaker than the above," he should choose a less roundabout way of doing so than by saying that my (4), (8), and (10) do not imply such differentiability.

Finally, there are a number of points in the discussion in Beutler's final paragraph above with which I could agree, except that his last sentence should read " . . . must *sometimes* be used," and even this should be accompanied by an explanation that most such so-called ensemble averages are actually obtained by averaging things that are themselves individual time averages. But there are certainly many problems in engineering in which one is interested in considerations of the type discussed in Beutler's final paragraph, and I do not wish it inferred that I am unaware of such problems. However, there are also many problems in which one is interested in the behavior of a specific autocorrelation function—*not* a covariance function. Both my earlier note and the remarks in my letter above were addressed to problems of this type. I am not only willing to infer that ensemble properties are not appropriate to such problems—I should say that it is manifestly obvious that they are not. Indeed, this is simply a tautology.

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[12] Received by the IRE, February 24, 1958.

[13] R. H. Cameron and W. T. Martin, "Transformations of Wiener integrals under a general class of linear transformations," *Trans. Amer. Math. Soc.*, vol. 58, pp. 184–219; 1945.

[14] M. Kac, "On the average of a certain Wiener functional and a related limit theorem in calculus of probability," *Trans. Amer. Math. Soc.*, vol. 59, pp. 401–414; 1946.

[15] S. Bochner, "Harmonic Analysis and the Theory of Probability," University of California Press, Berkeley and Los Angeles, Calif.; 1955.

[16] G. Baxter, "Wiener process distributions of the 'arcsine law' type," *Proc. Amer. Math. Soc.*, vol. 7, pp. 738–741; August, 1956.

[17] F. Kozin, "A limit theorem for processes with stationary independent increments," *Proc. Amer. Math. Soc.*, vol. 8, pp. 960–963; October, 1957.

### *Letter from Mr. Wiener*[18]

Brennan has shown me his correspondence with Beutler. I must say that Beutler's assertion that the definition used by Brennan differs from the definition customarily used is contrary to the facts. There are literally thousands of books and papers in which exactly that definition is used. No inconsiderable number of these papers have appeared in this very journal. Furthermore, I have never heard of any term other than "autocorrelation function" that has even been proposed for that function.

Beutler's remark that the autocorrelation function of a Brownian motion fails to exist is not true in the absence of further qualification, but even if suitably qualified, it would be analogous to a remark to the effect that Fourier transforms are not useful for peeling apples. It is true that they are not.

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[18] Received by the IRE, February 24, 1958.

## Some Properties of Lightning Impulses Which Produce Whistlers[*]

The purpose here is to report some newly-discovered properties of the lightning impulses which produce "whistlers." These remarkable very low frequency (0.5–35 kc) radio signals result from the dispersion of lightning energy which has traveled *through* the ionosphere, following lines of force of

[*] Received by the IRE, April 7, 1958. This research was sponsored in part through the Air Force Office of Scientific Res. of the Air Res. and Dev. Command under Contract No. AF18(603)-126.

the earth's magnetic field.[1–3] Their length, of the order of one second, and their descending pitch distinguish them from ordinary atmospherics, such as "clicks," "tweeks," and "rumblers,"[7] which are confined to the space *between* the earth and the ionosphere. These "direct" signals, which we shall refer to as "sferics," have durations from less than 1 to more than 50 msec. The sferic from a discharge which produces a whistler can be used to study the properties of the causative impulse. Such a study has been initiated at Stanford and Boulder, and the first results, reported here, are somewhat surprising.

Prior to this investigation, it was known that lightning impulses associated with thunderstorms did, on occasion, produce whistlers.[1,2] Some eye-witness accounts of visible lightning preceding whistlers were also known.[4] Vertical discharges from an isolated "cell" were observed for a short period close to Boulder by one of the authors. Each flash produced a clearly audible "long" whistler. (A "long" whistler is one which has made a round trip between the point of origin and a point in the opposite hemisphere.) It also has been noted by most whistler observers that on many occasions the sferics preceding whistlers produce a unique "sound," distinctly different from the usual clicks and tweeks.[5] The aural impression is not unlike the thud of a mud ball striking a solid surface, and suggests the presence of unusually strong low frequency components. On the other hand, the present authors have observed that ordinary tweeks also precede whistlers in many cases.

Sferic waveforms are recorded with accurately calibrated equipment developed by the National Bureau of Standards, while broad-band direction-finding information and calibrated whistler recordings are made with crossed-loop equipment, similar to that designed at Stanford for the study of whistlers. The use of the broad-band receivers is a significant departure in the field of direction-finding measurements on sferics. It offers the possibility of eliminating, or at least greatly reducing, the type of crossed-loop direction-finding error which results from sky-wave interference. For each fix determined by the direction finders, the two corresponding waveforms were analyzed for their amplitude spectra. Required calculations were carried out by Dr. H. H. Howe, National Bureau of Standards Boulder Laboratories, using a digital computer.

At each station the trigger and amplitude sensitivities were adjusted so that the sferics of interest were recorded simultaneously at the proper levels. Positive identification of the same sferic on the Boulder and Stanford records was made with the aid of a timing pulse accurate within plus or minus 1 msec. This pulse was triggered by the Boulder sweep and transmitted by telephone line to Stanford, where it was recorded on the waveform film. Each sferics-waveform channel was calibrated in terms of the strength of the vertical component of the electric vector in volts per meter. Whistlers were recorded on magnetic tape running at a speed of 15 inches per second at both Stanford and Boulder. The time scales of the sferics film and whistler tape were matched with the aid of easily recognized sferics.

While examining whistler and sferics records made during the evening of September 12 and the early morning of September 13, 1956, it was noticed that a unique sferic waveform, having several cycles at a frequency near 5 kc, preceded nearly every whistler. At the times of this study, the sferics which preceded whistlers were of such an unusual character that it was possible to predict the occurrence of the whistler by observation of the waveform alone. In this way, several whistlers were found which had been overlooked in the first aural analysis of the magnetic tape.

An example of the frequency-vs-time analysis of whistlers recorded simultaneously at Stanford and Boulder is shown in Fig. 1. The numerous vertical lines are caused by sferics; note the agreement in the times of reception of the sferics at Boulder and Stanford. Whistlers are evidenced as dark traces descending in frequency from about 12 kc to approximately 2 kc in an interval of about one second.

Note that there are three whistler traces on the Boulder record (top of Fig. 1), and that the measured time intervals between the first and second whistler is 0.127 second, and that between the second and third is 0.412 second. The dispersions of these whistlers which were calculated using the Eckersley dispersion law are plotted at the bottom of Fig. 1. The intersections of the dispersion curves with the time axis give the approximate times of occurrence of the sferics which caused the whistlers. It is not possible to identify the causative sferics on the whistler record itself because of the relatively poor time resolution of this trace and the high level of atmospheric activity. Fig. 2 gives a portion of the waveform record made at Boulder at the times the causative sferics must have occurred. This record was made on film moving at a speed of $3\frac{3}{4}$ inches per second. The five sferics shown in this figure are the only ones that were recorded in an interval of about two seconds of the times suggested by the Eckersley dispersion method. The combination of sferics 1, 2, and 3, which occurred within an interval of 0.0325 second, apparently produced the first whistler trace, which appears to be somewhat broader than the second and third whistler traces. Sferic 4 apparently produced the second whistler trace, and sferic 5 the third. This method of matching the times of occurrence of sferics and whistlers gave excellent agreement throughout the entire five minutes of data. Since the three whistlers have the same dispersions and arrived with the same time spacings as the sferics, it is highly probable that this was a multiple-flash group of whistlers.[1] The records of Figs. 1 and 2 are believed to be the first reported observation of sferic waveforms and their corresponding whistlers of the "long" variety. Three multiple echoes of each of these whistlers were observed on the original analysis, but it was necessary to cut the record as shown to facilitate its reproduction.

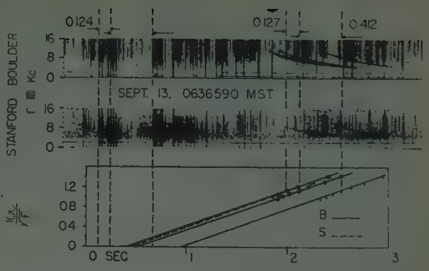

Fig. 1—Whistlers recorded simultaneously at Boulder, Colo., and Stanford, Calif.

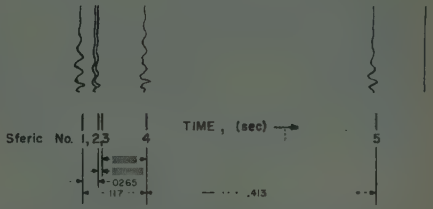

Fig. 2—Sferics recorded at Boulder, Colo. Vertical antenna response, September 13, 1956, 0636:59.0 MST.

The "dispersion" commonly reported by whistler workers is calculated using the Eckersley dispersion law. Note that in Fig. 1, the times of occurrence of the whistler-producing sferics calculated using the Eckersley dispersion law are about 0.3 second later than the recorded times. Similar time discrepancies were noted by Storey, who suggested several possible explanations.[2] A new explanation based on the failure of the Eckersley law when the gyrofrequency is not large compared with the wave frequency was advanced by Helliwell, *et al.*[3] This point will not be elaborated upon; however, if the Eckersley dispersion law is used to identify the causative sferic, there is a strong possibility that the wrong sferic may be selected. Time discrepancies amounting to as much as 0.4 second were found in other examples in both the Boulder and Stanford records.

The examples given in Figs. 1 and 2 were recorded between 0635 and 0640 MST on September 13, 1956. Thunderstorms were known to be in progress in various parts of the United States during this period. However, when the positions of lightning flashes which caused whistlers were plotted on a map, all were found to occur either near coastlines (Gulf of Mexico, or California-Mexico) or over water. In this particular test, no whistler-causing sferics were found to occur over land. (Whistler-producing sferics originating over the sea were observed in other tests.) This result suggests existence of some factor related to the ocean which enhances the amount of energy radiated at low frequencies. Possibly, the conductivity of the sea or the meteorology of ocean thunderstorms are significant factors.

At Boulder the trigger sensitivity of the sferics channel was set at 0.07 volt per

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[1] T. L. Eckersley, "Musical atmospherics," *Nature, London*, vol. 135, p. 104; January, 1935.

[2] L. R. O. Storey, "An investigation of whistling atmospherics," *Phil. Trans. Roy. Soc., London, Ser. A*, vol. 246, pp. 113–141; July, 1953.

[3] R. A. Helliwell, J. H. Crary, J. H. Pope, and R. L. Smith, "The 'nose' whistler, a new high latitude phenomenon," *J. Geophys. Res.*, vol. 61, pp. 139–142; March, 1956.

[4] T. L. Eckersley, "Developments in the study of radio wave propagation," *Marconi Rev.*, p. 5; July-August, 1951.

[5] M. G. Morgan and H. E. Dinger, "Observations of whistling atmospherics at geomagnetically conjugate points," *Nature, London*, vol. 177, pp. 29–31; January 7, 1956.

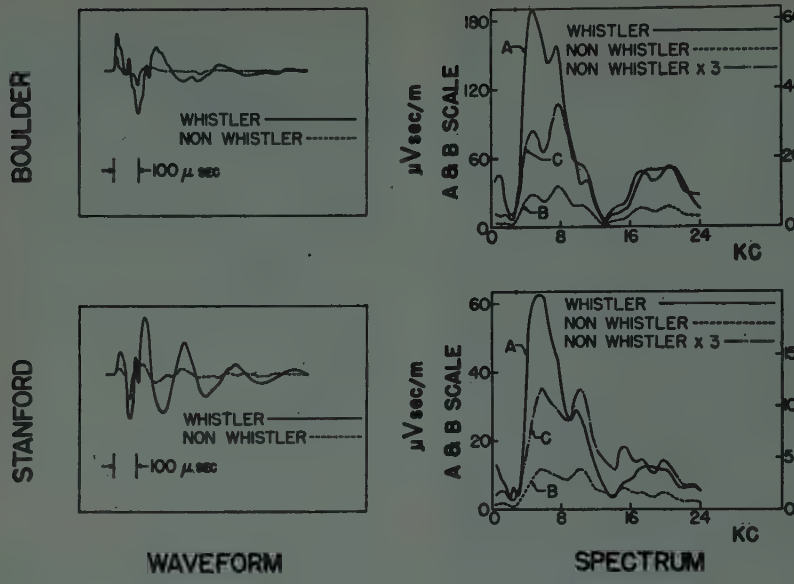

Fig. 3—Whistler sferic vs nonwhistler sferic recorded at Boulder, Colo., and Stanford, Calif., September 12, 1956, 2035 MST.

meter. During this 5-minute period, 310 sferics were recorded at Boulder: 254 of the sferic waveforms were characterized by no components at a frequency near 5 kc and no corresponding whistlers were audible; 51 sferics contained several half cycles at a frequency near 5 kc and all but five which had very low amplitudes preceded audible whistlers. The noise level of the whistler-recording channel was about 30 microvolts per meter.

A comparison was made of the waveforms of sferics which produced whistlers and those, occurring in the same storm, which did not cause whistlers. Such a comparison is illustrated in Fig. 3, which gives the waveforms and spectra of whistler-producing and nonwhistler-producing sferics as recorded at Boulder and Stanford on September 12, 1956, at 2035 MST. The lightning flashes which produced these two sferics occurred in the same storm in South Dakota. The waveforms of the nonwhistler-producing sferic recorded at Boulder and Stanford, and its corresponding spectra, are superimposed in Fig. 3 for comparison. It is evident that the whistler-producing sferic possessed a larger amount of energy at frequencies lower than 10 kc than the nonwhistler-producing sferic. The spectra of the whistler and nonwhistler-sferics were approximately normalized at a frequency of 10 kc by multiplying the latter by a factor of three. These curves are also given in Fig. 3 and are designated by "×3." It is the relatively large amount of energy at frequencies near 5 kc (evidenced as several half cycles at a frequency near 5 kc in the waveform) that appears to characterize the whistler-producing sferics.

Propagation attenuation rates at very low frequencies[6,7] indicate that the attenuation rate is about 2 db/1000 km at 10 kc and increases to about 6 db/1000 km at frequencies between about 1 and 5 kc. Thus, the peak of the source spectrum can be expected to be somewhat lower in frequency than that of the spectrum observed at great distances from the source.

It is of interest to note that the transmission coefficient of the ionosphere has a maximum in the VLF band at frequencies in the range from 1 to 5 kc, which could partially explain the relative importance of this portion of spectrum. This suggestion was advanced at the recent VLF Symposium.[8]

On the basis of the results described in this note, the following conclusions have been reached.

1) A characteristic waveform is often, though not necessarily always, associated with the impulse which produces a whistler. It is distinguished by an intense energy peak at frequencies near 5 kc. Its frequency of occurrence is believed to be relatively small (as is that of whistlers), compared with the total number of sferics recorded. It seems, therefore, that statistics of ordinary sferics cannot be applied to the study of the whistler sources. These results do not imply, however, that other types of impulses do not produce whistlers.

2) Whistler-producing discharges appear to be more frequent over sea than over land.

3) The time of origin of a whistler should not be calculated from the Eckersley law of dispersion, which predicts a time up to 0.4 second after the true time. Identification of the causative impulse should be based on waveform analysis as well as the time of occurrence.

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[6] J. R. Wait, "The attenuation vs frequency characteristics of VLF radio waves," Proc. IRE, vol. 45, pp. 768–771; June, 1957.

[7] F. W. Chapman and R. C. V. Macario, "Propagation of audio-frequency radio waves to great distances," *Nature, London*, vol. 177, p. 930; May, 1956.

[8] J. R. Wait, "Discussion on sferics and whistlers," *Symp. on Propagation of V.L.F. Radio Waves*, Boulder, Colo., vol. 4, p. 23; January, 1957.

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## Hyperbolic Analogs Using Varistors*

Hellstrom[1] has indicated that hyperbolic analogs could be obtained by manipulating the expression:

$$I = I_s[\exp(qV/kt) - 1]$$

for semiconductor diodes.

It can be shown[2] that sinh functions can be obtained from such devices using the equivalent circuit illustrated in Fig. 1. This equivalent circuit is empirical in nature but provides an adequate representation of a large variety of varistors over a considerable range of both positive and negative voltages.

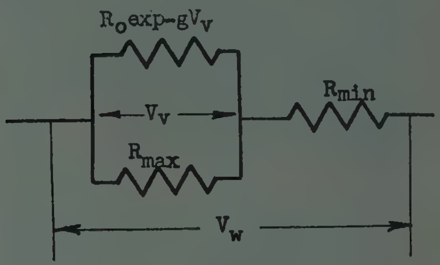

Fig. 1.

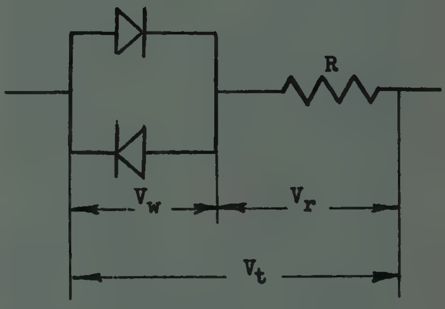

Fig. 2.

It can be shown, by connecting a symmetrical varistor, formed from two similar semiconductor diodes, in series with a linear resistor as indicated in Fig. 2, that the relation between $V_r$, $V_w$, and $V_t$ is given by

$$V_r = \frac{R}{R + R_{\min}}[V_t - k_1 \sinh^{-1} k_2 V_t]$$

$$V_w = \frac{R_{\min}}{R + R_{\min}}[V_t + k_1 \sinh^{-1} k_2 V_t].$$

If $R$ is made large with respect to $R_{\min}$ then these approximate to

$$V_r = V_t - k_1 \sinh^{-1} k_2 V_t.$$

$$V_w = \frac{R_{\min}}{R} k_1 \sinh^{-1} k_2 V_t.$$

The latter equation gives a convenient analog for the inverse hyperbolic sine function.

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* Received by the IRE, April 16, 1958.

[1] M. J. Hellstrom, "Hyperbolic analogs," Proc. IRE, vol. 46, p. 502; February, 1958.

[2] G. W. Holbrook and A. L. Dulmage, "Some characteristics of metallic varistors," *Electronic Eng.*, vol. 29, pp. 386–392; August, 1957.

## Radio Reflections from Satellite-Produced Ion Columns*

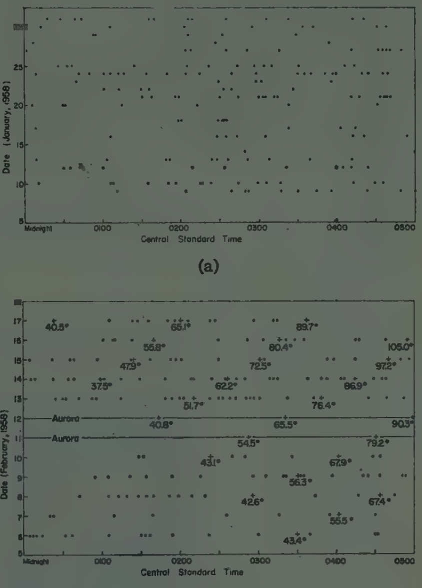
It has been reported that ionization columns produced by artificial satellites traversing the upper atmosphere have been observed by radio-reflection techniques.[1,2] Data taken at the University of Illinois do not indicate the presence of ion columns while the satellites are extremely high in the atmosphere.

Since late in December, 1957, the signal strength of WWV (20 mc) has been recorded at the University of Illinois as a function of time. The antenna used is a single dipole, the receiver is a Collins R-390A/URR communications receiver, and the recording device is an Esterline-Angus recording milliammeter operated at a tape speed of one foot per hour. Since the tape speed is too slow for the one-second timing marks to be useful, the carrier-off periods every hour on the three-quarter hour are used for timing marks on the tape.

Several classes of signal variation are found on the tapes. The most obvious (other than the timing marks and noise) is the diurnal increase and decrease of the signal strength due to the change in the over-all ionization density in the upper atmosphere. During the daylight hours the signal strength (WWV) becomes so high that most other variations are completely overshadowed. Between 8:00 and 11:00 P.M. each day the signal level drops to such a level that other effects become observable, and remains at this low level until shortly before sunrise. Pulses due to automotive ignition noise are found on the records and sometimes show up as an average increase of signal strength over a period of a few minutes because of the integrating effect of the recorder movement. There are indications that auroral reflections of WWV are recorded as strong, rapidly fluctuating signals with a longer period fluctuation superimposed on the rapid fluctuations. The auroral signals have been correlated with visual observations of the auroras of February 10–11, 1958, and March 12–13, 1958.

The increases of signal intensity with which we are most concerned are the very short high-intensity bursts commonly associated with meteor ionization in the upper atmosphere (80–120-km height). These bursts only appear after the daytime ionization density has decreased to such a low level that the signal of WWV no longer has strength to be continuously observable on the tape record. The bursts of increased signal, in the past, have been attributed to specular reflections of WWV from the ion columns produced by meteors. Recently these bursts have also been attributed by Kraus[1,2] to columns of ionization associated with U.S.S.R. artificial satellites in the upper atmosphere (200–800-km height).

Bursts due to meteor phenomena should be random events (the number per hour is increased by the presence of a meteor shower) and bursts due to U.S.S.R. satellites should be periodic from day to day for a specific pass of the satellites across the line joining the transmitter (WWV) and the receiver (University of Illinois). Under favorable circumstances satellite reflections, if any, should be observable for three or four successive passages across the line between WWV and the University of Illinois (the line is almost coincident with the 40th parallel). Thus, there should be some days during which a periodicity of about 90–100 minutes should be found for a single day's bursts.



(a)

(b)

Fig. 1—(a) Bursts of WWV signal strength recorded during the month of January from midnight until 5 A.M. There were no satellite crossings of the 40th parallel between about 40 degrees and 120 degrees west longitude during the midnight to 5 A.M. period. (b) Bursts of WWV signal strength recorded during the month of February from midnight until 5 A.M. The crosses indicate the passages of the satellite 1957β across the 40th parallel. The numbers next to the crosses indicate the degrees west longitude of the crossing.

As can be seen from the plot of the bursts (Fig. 1) recorded at the University of Illinois, no such valid periodic variations are found. These data must be analyzed statistically and a correlation made between the daily records. As is possible in most cases where the occurrence of a random event produces a high density of points, several periodic sets may be found if one allows sufficient latitude in choosing the individual points to match the curve one plots through the points. Since the periods of the satellites remain constant or change by only a small amount per day, variations of more than plus or minus about two minutes may not be allowed in the curve fitting. We are not able without ambiguity to fit curves indicating satellite ionization reflections to the data we have. We cannot, therefore, interpret any of our records as indicating the presence of a column of electrons associated with the U.S.S.R. 1957 artificial satellites.

Since it is quite certain that the satellites will produce a column of dense ionization as they come down through the atmosphere to low levels, observations are being taken at two widely separated (about 425 miles) points along the meridian 88.2 degrees west longitude. The correlation of the data from these two stations (located at Michigan College of Mining and Technology and the University of Illinois) should enable us to remove the meteor reflection bursts and preserve only the satellite reflections (if they are present). This should be possible since meteor columns are relatively short and a single meteor will probably not be observed from both stations, whereas the satellite will pass both stations and should be recorded at both. Perhaps as satellite 1957β moves down into the atmosphere it will be found that an ion column will be produced in an observable position. One would not expect to observe this for more than a few revolutions since the atmospheric density at the height, where an ion column would be produced, is great enough either to burn the satellite up completely or to slow it down enough that it would spiral into the earth in a very short time.

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* Received by the IRE, April 7, 1958. This work was supported in part by the Natl. Sci. Foundation through Grant No. Y/32.40/266 and the U. S. Navy under Contract No. Nonr-2395(00).

[1] J. D. Kraus, "Detection of Sputniks I and II by cw reflection," PROC. IRE, vol. 46, pp. 611–612; March, 1958.

[2] J. D. Kraus, "The last days of Sputnik I," PROC. IRE, vol. 46, pp. 612–614; March, 1958.

## Estimation of Dissipative Effects in Tchebycheff Symmetrical Filters*

With reference to the comprehensive article by Grossman on the synthesis of Tchebycheff symmetrical filters,[1] it may be of interest to point out that, as in other cases of network synthesis, the design procedure given readily lends itself to an estimation of the effect on over-all performance of incidental dissipation in the filter elements.

Such a check, made prior to constructing the filter, may be of considerable value in revealing departures from the ideal Tchebycheff insertion loss characteristic, especially in the region of cutoff frequencies. These departures are likely to be serious with band-pass and band-stop filters having a small bandwidth relative to the mean frequency.

The method consists merely of moving to the left on a complex frequency plot the position of each pole and zero of the normalized low-pass insertion voltage function by a fixed amount, $d$, dependent on the averaged $Q$ values of the inductors and capacitors to be used.[2,3] The resulting transfer function no longer follows exactly the desired equal ripple response, and its value at selected frequencies may be found graphically or numerically by considering the lengths of the vectors joining the new critical points

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* Received by the IRE, April 7, 1958.

[1] A. J. Grossman, "Synthesis of Tchebycheff parameter symmetrical filters," PROC. IRE, vol. 45, pp. 454–473; April, 1957.

[2] S. Darlington, "Synthesis of reactance 4-poles," *J. Math. Phys.*, vol. 18, pp. 257–353; September, 1939.

[3] H. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand Co. Inc., New York, N. Y., 1st ed., p. 217; 1949.

to the point on the vertical axis representing the normalized frequency in question.[4,5]

Now the positions of both poles and zeros appropriate to the ideal (lossless) transfer function appear explicitly in the design formulas given by Grossman,[1] while the required value of $d$ is found from a knowledge of the expected $Q$ values of the filter elements.

Thus, using Grossman's symbols throughout, and referring to his Figs. 5–8,[1] the coordinates of the zeros are $-a_0$; $-a_1 \pm jb_1$; $\cdots -a_m \pm jb_m$, while those of the poles are $\pm j/\Omega_1$; $\pm j/\Omega_2 \cdots \pm j/\Omega_m$.

The dissipation factor $d$ is found:

1) For high-pass and low-pass applications as

$$d = \frac{1}{2}\left(\frac{1}{Q_L} + \frac{1}{Q_C}\right)$$

where

$$Q_L = \frac{2\pi F_0 L}{R}, \qquad Q_C = \frac{G}{2\pi F_0 C}$$

are respectively the average $Q$ values of the inductors and capacitors to be used, measured at the "crossover" frequency of the final filter, $F_0 = \sqrt{F_p F_a}$ (see Fig. 4[1]).

2) For band-stop and band-pass filters as

$$d \doteq \frac{1}{\Delta}\left(\frac{1}{Q_L} + \frac{1}{Q_C}\right)$$

where

$$\Delta = \frac{1}{F_m} \cdot \sqrt{(F_p - F_{-p})(F_a - F_{-a})}$$

and $Q_L$, $Q_C$ are now measured at the mean frequency, $F_m$. (It is here assumed that $\Delta \ll 1$.)

As an illustration, the following example is given.

Type of filter: Band-pass (insertion loss characteristic to display geometric symmetry about the mean frequency).

Cutoff frequencies: $F_p = 19.211$ kc, $F_{-p} = 16.211$ kc.

Stop-band limits: $F_a = 19.845$ kc, $F_{-a} = 15.693$ kc.

Mean frequency: $F_m = \sqrt{F_p \cdot F_{-p}} = \sqrt{F_a \cdot F_{-a}} = 17.65$ kc.

Pass band loss (max): $\alpha_p = 0.125$ db.

Stop-band loss (min): $\alpha_a = 40.0$ db.

Average $Q$ of inductors: $Q_L = 177$ $\Big\}$ measured at $F_m$.
Average $Q$ of capacitors: $Q_C = 1000$ $\Big\}$

First, the selectivity factor $k$ is evaluated:

$$k = \frac{F_p - F_{-p}}{F_a - F_{-a}} = 0.7225.$$

It is now found (using Fig. 9 and Table I of Grossman) that a two-section filter with lossless components will closely approximate the desired performance. Thus for $\alpha_p = 0.125$ db and $k = 0.7225$, minima of 39.5 db will be achieved in the stop band. Applying these three values in Fig. 6,[1] the following relevant constants are evaluated in the normalized low-pass design:

$$\begin{aligned} \Omega_1 &= 0.558{,}46 & \Omega_2 &= 0.820{,}96 \\ a_0 &= 0.549{,}53 & & \\ a_1 &= 0.333{,}24 & b_1 &= 0.670{,}80 \\ a_2 &= 0.084{,}755 & b_2 &= 0.896{,}51 \\ \Omega_{\mathrm{I}} &= 0.307{,}54 & \Omega_{\mathrm{II}} &= 0.728{,}06. \end{aligned}$$

The resulting plot of critical points of the insertion voltage transfer function in the complex frequency plane is sketched in Fig. 1.

The corresponding points for the dissipative filter are obtained by adding $-d$ to all coordinates above or alternatively, for convenience, by merely shifting the $j\Omega$ axis $OY$ a distance $+d$ to the position $O'Y'$ as shown.

The insertion loss in decibels at any chosen point $j\Omega$ on the normalized frequency scale is given as

$$\alpha = 20 \log_{10} V_0 \cdot \left| \frac{(p-p_0)(p-p_1)(p-p_1^*)(p-p_2)(p-p_2^*)}{(p-j/\Omega_1)(p+j/\Omega_1)(p-j/\Omega_2)(p+j/\Omega_2)} \right|$$

where $p = j\Omega$ is taken along $OY$ for the ideal filter, and along $O'Y'$ for the dissipative filter.

$$\begin{aligned} p_0 &= -a_0 \\ p_1 &= -a_1 + jb_1 & p_2 &= -a_2 + jb_2 \\ p_1^* &= -a_1 - jb_1 & p_2^* &= -a_2 - jb_2 \end{aligned}$$

$$V_0 = \frac{1}{\Omega_1^2 \Omega_2^2}\left[(10^{\alpha_a/10} - 1)(10^{\alpha_p/10} - 1)\right]^{1/4}.$$

In this case

$$\begin{aligned} d &\doteq \frac{1}{\Delta}\left(\frac{1}{Q_L} + \frac{1}{Q_C}\right) \\ &= \frac{1}{0.20}(0.00565 + 0.001) \\ &= 0.0333. \end{aligned}$$

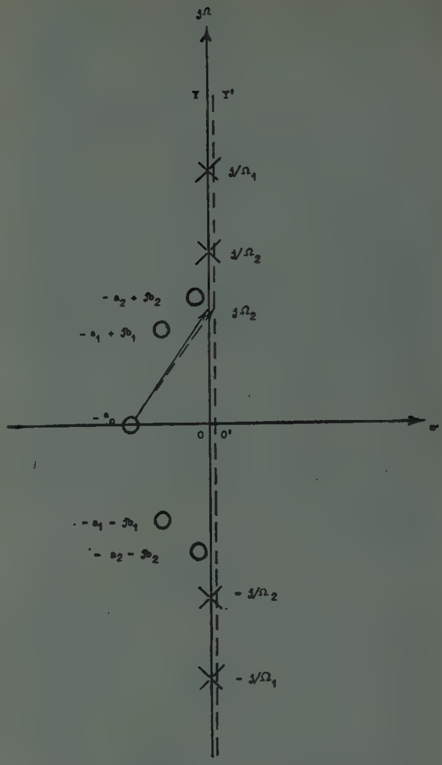

Fig. 1—Critical points on insertion voltage function, two-section filter.

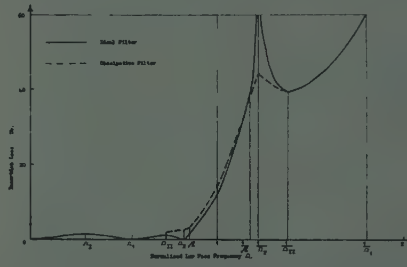

Fig. 2—Insertion loss of ideal and dissipative two-section filters in region of cutoff.

TABLE I

| Normalized low-pass frequency | $\Omega_{\mathrm{II}} = 0.728$ | $\Omega_2 = 0.821$ | $\sqrt{k} = 0.850$ | 1.000 | $1/\sqrt{k} = 1.176$ | $1/\Omega_2 = 1.218$ | $1/\Omega_{\mathrm{II}} = 1.374$ |
|---|---|---|---|---|---|---|---|
| Insertion loss, ideal filter db | 0.125 | 0.000 | 0.125 | 12.3 | 39.5 | ∞ | 39.5 |
| Insertion loss, dissipative filter db | 1.9 | 2.7 | 3.1 | 14 | 38 | 45 | 40 |

The evaluation of the constant multiplier $V_0$ may be made graphically, since the loss at points $p = j\Omega_s$ must be zero in the case of the ideal filter ($d = 0$). Thus at the second point of zero loss in the pass band $p = j\Omega_2 = j0.820{,}96$ taken along $OY$.

Then

$$\alpha = 0 = 20 \log_{10} V_0 \cdot \frac{(0.988)(0.366)(1.53)(0.114)(1.72)}{(0.970)(2.61)(0.397)(2.04)}$$

therefore $V_0 = 19.0$.

The loss with the dissipative filter at the same frequency may now be found by taking $p = j\Omega_2$ along $O'Y'$.

$$\begin{aligned} \alpha' &= 20 \log_{10} 19.0 \frac{(1.01)(0.396)(1.54)(0.140)(1.72)}{(0.970)(2.61)(0.399)(2.04)} \\ &= 2.7 \text{ db.} \end{aligned}$$

The loss at some of the other significant points is tabulated in Table I and sketched in Fig. 2. If desired, the actual band-pass characteristic may be plotted by replacing points on normalized low-pass frequency scale by the corresponding band-pass frequencies using the transformation given in Grossman's Fig. 4.[1]

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[4] H. J. Orchard, "Design of Four Terminal Reactance Networks," British Post Office Res. Rep. No. 13135; 1949.

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# Contributors

C. C. Davis

C. C. Davis was born in Fenton, Mich. on November 27, 1893. He attended the University of Michigan, Ann Arbor, until joining the A.E.F. in 1917. His two years in France included attendance at the University of Toulouse. After joining with Frank D. Fallain to found the Flint Broadcasting Company, he left to join Electrical Research Products, Inc. when sound pictures were generally introduced in 1928. After a time in the theater engineering field, he was transferred to the E.R.P.I. headquarters in New York, and later to Hollywood. He has been with E.R.P.I. and its successor, the Westrex Corporation, since 1940, except for an interval in World War II when he engaged in radar work for the Radio Division of Western Electric.

His work has resulted in several patents which include film and disk drive mechanisms and anti-crosstalk and hum pickup features in magnetic heads. His tight-loop film pulling mechanism is used extensively and was given an award by the Academy of Motion Picture Arts and Sciences; it has become known as the Davis Drive. He was awarded the Samuel L. Warner Memorial Award by the Society of Motion Picture and Television Engineers for his developments in motion picture sound equipment.

He is a member of the Sapphire Group of Hollywood and the Audio Engineering Society, and a fellow of the Society of Motion Picture and Television Engineers.

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C. Ellyett

C. Ellyett was born in Christchurch, New Zealand, on January 10, 1915. He received the M.S. degree in chemistry from the University of New Zealand in 1936 and in physics in 1937. He joined the staff of the Department of Physics of the University of Canterbury (N.Z.) as assistant lecturer in 1938, becoming lecturer in 1944 and senior lecturer in 1952.

During World War II he was in charge of the scientific aspects of ionospheric work in New Zealand and the South Pacific for the New Zealand Government. During 1943 and 1944 he spent some time in Australia and America on ionospheric work. From 1947 to 1949 he was at Manchester University, where he was awarded the Ph.D. degree for research work at Jodrell Bank on the radar detection of meteors.

Returning to New Zealand in 1950, he established and has since directed a radio and radar field station, as part of the University of Canterbury. He is presently working in the field of Southern Hemisphere meteor activity, and the relation of meteors to sporadic *E*.

He has been a New Zealand representative to URSI in Australia in 1953, and New Zealand leader in Sweden in 1948 and America in 1957. For six months in 1957 he was a consultant at the Boulder Laboratories of the National Bureau of Standards, working on meteors and VHF forward scatter.

Dr. Ellyett is a member of the New Zealand Committees for Radio Research, Defence Research and Ross Dependency (Antarctic) Research.

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P. J. Franklin

Philip J. Franklin (A'43–SM'51) was born in Riverside, Calif., on October 25, 1908. He attended the University of California at Los Angeles, where he received the A.B. degree in 1931. From 1932 to 1942 he was a teacher in public schools in California.

Between 1943 and 1953 Mr. Franklin worked as physicist for the National Bureau of Standards. Since that time he has held the position of physical science administrator and chief of the components and materials branch of the Diamond Ordnance Fuze Laboratories, Washington, D. C., where he has engaged in research in plastics, components, electronic instrumentation, casting resins, and printed circuits.

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J. G. Frayne

John G. Frayne was born in Wexford Ireland, on July 8, 1894. He matriculated at Trinity College, Dublin, in 1912 and immigrated to the United States in 1914. He entered Ripon College, Ripon, Wis., in January, 1915 and graduated with the A.B. degree in physics in June, 1917.

Following military service in World War I, when he attained the rank of Second Lieutenant in the U. S. Army Signal Corps, he began graduate work in physics at the University of Minnesota, Minneapolis, and received the Ph.D. degree in 1921. He served as an instructor there in mathematics and physics from 1919 to 1922. He became professor of physics at Antioch College, Yellow Springs, Ohio, in 1922, remaining there until 1928 when he was awarded a National Research Council Fellowship at California Institute of Technology, Pasadena.

In 1929 he joined the engineering staff of the Electrical Research Products, Inc. in Hollywood. He has been with that company and its successor, the Westrex Corporation until the present time.

He has been active in developing and improving sound recording techniques in optical, magnetic, and disk media. He was responsible for the development of the integrating sphere densitometer, now universally used in motion picture film laboratories, and the intermodulation measurement technique which were recognized by awards from the Academy of Motion Picture Arts and Sciences. He has been engineering manager in the Hollywood Division of Westrex since 1949.

Mr. Frayne is a past president of the Society of Motion Picture and Television Engineers and received the Journal Award of the Society in 1940 and the Progress Medal Award of the Society in 1947. He is also a Fellow of the Audio Engineering Society.

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E. A. Gerber

Edward A. Gerber (A'50–SM'56) was born in Fuerth, Bavaria, Germany, on April 3, 1907. He received his education at the Institute of Technology in Munich and Berlin, Germany. From the former, he obtained the M.S. degree in 1930, and the Ph.D. degree in 1935, both in physics. In 1935, he joined the scientific staff of the Carl Zeiss Works, Jena, Germany, and was in charge of research and development in piezoelectric crystals.

Dr. Gerber arrived in the United States in 1947, and from that time until 1954, he was a consultant to the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., on all matters pertaining to frequency control.

Since 1954, he has been director of the Frequency Control Division, U. S. Army Signal Research and Development Laboratory, at Fort Monmouth. He is the author of numerous papers.

He is an Army member of the Working Group on Frequency Control Devices, Advisory Group on Electronic Parts, and a U. S. Delegate on the Technical Committee on Piezoelectric Crystals, International Electrotechnical Commission.

Myron S. Glass (A'36–VA'39–M'55–SM'56) was born on May 25, 1902, in Eddyville, Iowa. He received the M.S. degree in physics from the University of Chicago, Chicago, Ill., in 1926.

M. S. Glass

He joined the technical staff of Bell Telephone Laboratories, New York, N. Y., in 1926. At present he is with their Murray Hill Laboratory.

From 1926 to 1941, Mr. Glass was engaged in development work on various electronic devices, principally cathode-ray tubes and phototubes. From 1941 to 1954, he was working on the development of magnetrons. Since 1954, he has been engaged in development work on magnetic focusing circuits for traveling wave tubes.

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James H. Green, Jr., was born on May 29, 1920, in La Romana, Dominican Republic. He received the B.S. degree in physics from Yale University in 1941.

J. H. Green, Jr.

Mr. Green held the rank of Captain in the Signal Corps, United States Army, during World War II, serving as radio and radar officer, Delta Base Section, and as program director, European Theater Signal Corps School. He returned to civilian life in 1946 as an engineer with RCA Communications at Rocky Point, L. I.

From 1947 to 1951 he was with the Fredric Flader Company, where he became manager of the Engineering Physics Department. In 1951 he joined Bell Aircraft as program planner on the RASCAL Program.

Since 1953 Mr. Green has been engaged in research and development on advanced communication systems for Sylvania Electronic Systems, and is at the present time an engineering manager in Sylvania's Amherst Engineering Laboratories.

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A. E. Karbowiak was born on March 1, 1923 in Warsaw, Poland. He received the B.S. degree in 1950 and the Ph.D. degree in electrical engineering in 1954 from the University of London.

A. E. Karbowiak

From 1954 until the present he has been engaged as a Group Leader with Standard Telecommunication Laboratories, Limited, in Middlesex, Eng., conducting research on microwaves.

Dr. Karbowiak is an associate member of the Institution of Electrical Engineers, London.

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Peter T. Kirstein (S'55–A'58) was born on June 20, 1933, in Berlin, Germany. He was educated in England, and received the B.A. degree in mathematics and mechanical sciences in 1954, from Cambridge University. In 1955, he received the M.Sc. and in 1957, the Ph.D. degree in electrical engineering from Stanford University.

P. T. Kirstein

He worked for the U. S. Army Corps of Engineers during 1951 and 1952. From 1954 to 1957 he was employed as a research assistant, and since 1957, as a research associate, at the Microwave Laboratory of Stanford University, where he has carried out research on propagating circuits, electromagnetic theory, and electron guns.

Dr. Kirstein is a member of Sigma Xi.

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Lawrence F. Koerner (A'29–VA'39–M'55) was born in Niles, Mich., on February 25, 1897. He received the B.S. degree from Colorado College, Colorado Springs, in 1923, and in the following year the M.S. degree from Harvard University, Cambridge, Mass.

L. F. Koerner

He joined the staff of Bell Telephone Laboratories, Inc., in 1924, and has been concerned with the development of vacuum-tube oscillators, detectors, frequency-measuring equipment, and crystal units and crystal oscillator circuits for transmitters and receivers. Mr. Koerner holds several patents on crystal equipment and is the author of articles on the testing and calibration of quartz crystals.

He is a member of the Harvard Engineering Society, Delta Epsilon, and Pi Kappa Alpha.

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Hope Leighton was born in Alta Vista, Kan., September 17, 1920. During World War II she was a member of the Women's Army Corps, serving as a radio mechanic. She received the B.S. degree in physics from Kansas State College, Manhattan, Kan., in 1949. Since then she has been affiliated with the National Bureau of Standards where she was first involved in textiles research. From 1951 to 1953 she was with the North Pacific Radio Warning Service of the Radio Division of NBS in Anchorage, Alaska. Since 1955 she has been mainly concerned with VHF propagation studies.

H. Leighton

She is a member of the American Geophysical Union, Phi Kappa Phi, and Pi Mu Epsilon, and an associate member of the Research Society of America.

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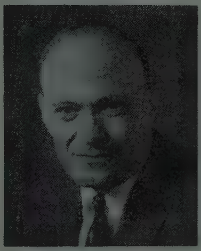
Kurt O. Otley was born in Vienna, Austria, on October 28, 1906. He received the Ph.D. degree in chemistry from the University of Vienna in 1931.


K. O. Otley

In 1939–1940 he was a research chemist with Crompton, Parkinson, Ltd., London, Eng. He came to the United States in 1940 and was a chemist with several American industrial companies until 1949.

Between 1949 and 1951 Dr. Otley held the post of research associate at Pennsylvania State University, University Park. He was a chemist for the National Bureau of Standards from 1951 until 1953, when he became a chemist, then a physicist, for the Diamond Ordnance Fuze Laboratories, Washington, D. C. At DOFL Dr. Otley has been engaged in research in solid-state physics, dielectrics, and electrical components.

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Chester H. Page (A'41–SM'48–F'56) was born on November 13, 1912, in Providence, R. I. He received the B.S. and M.S. degrees in 1934 from Brown University, and the Ph.D. degree from Yale University, New Haven, Conn., in 1937.

C. H. Page

From 1937 to 1941 he taught at Lafayette College, Easton, Pa., and has been with the National Bureau of Standards ever since.

He is the author of two books, "Physical Mathematics" in 1955 and "The Algebra of Electronics" due to be published this year.

Dr. Page is a member of the American Physical Society, Philosophical Society of Washington, Sigma Xi, and Phi Beta Kappa. and is editor of the *Journal of the Washington Academy of Sciences.*

E. A. Sack (S'49–A'55–M'56) was born in Pittsburgh, Pa., on January 31, 1930. He attended the Carnegie Institute of Technology, Pittsburgh, Pa. from 1947 to 1954, where he received the B.S., M.S., and Ph.D. degrees in electrical engineering. His graduate work dealt with nonlinear phenomena in ferroelectric circuits.

E. A. SACK

Since 1954 he has been a member of the staff of the Westinghouse Research Laboratories in the Television Section of the Electronics and Nuclear Physics Department. He was appointed project leader for that group in 1956 and in the following year became manager of the Dielectric Devices Section.

He has been active in the development of a number of solid-state devices for control and display.

Dr. Sack is a member of the American Institute of Electrical Engineers, Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Phi Kappa Phi.

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Robert L. San Soucie was born in Adams, Mass., on April 30, 1927. He received the A.B. degree in mathematics from the University of Massachusetts, Amherst, Mass., in 1949, the M.A. degree in mathematics in 1950 and the Ph.D. degree in mathematics (abstract algebra) in 1953 both from the University of Wisconsin, Madison, Wis., where he was a Wisconsin Alumni Research Foundation fellow from 1949 to 1951 and a National Science Foundation predoctoral fellow from 1952 to 1953.

R. L. SAN SOUCIE

Dr. San Soucie became a member of the faculty of the University of Oregon, Eugene, Ore., as an instructor in mathematics in 1953, and in 1955 became assistant professor of mathematics. During his four years at the University of Oregon, his major field of research was nonassociative ring theory. Since July, 1957, he has been an engineering specialist for Sylvania Electronic Systems, and currently heads the mathematics section of the Advanced Development Department of Sylvania's Amherst Engineering Laboratories.

He is a member of the American Mathematical Society, the Society for Industrial and Applied Mathematics, the Mathematical Association of America, Phi Kappa Phi, Sigma Xi, and Pi Mu Epsilon.

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Robert F. Shoemaker (S'51–A'53) was born in Washington, D. C., on November 12, 1925. From 1944 to 1945 he attended the United States Navy Radio Material School. From 1947 to 1952 he was a student at George Washington University, Washington, D. C.

R. F. SHOEMAKER

Mr. Shoemaker worked as an electrical engineer at the National Bureau of Standards for two years, 1951–1953. Since 1953 he has been an electronic scientist at the Diamond Ordnance Fuze Laboratories in Washington, where he has done work in solid-state physics, dielectrics, and electrical components.

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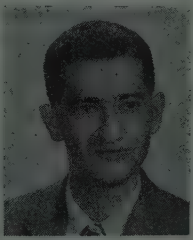
Stephen H. Unger (S'49–M'57) was born in New York City, N. Y., on July 7, 1931. In 1952, he received the B.E.E. degree from the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., and in 1953 and 1957 he received the S.M. and Sc.D. degrees, respectively, in electrical engineering from the Massachusetts Institute of Technology, Cambridge, Mass.


S. H. UNGER

From 1952 to 1955, he held summer positions with GE, IBM, and the Bell Telephone Laboratories. From 1955 to 1957, Dr. Unger was a research assistant at the Research Laboratory of Electronics at M.I.T., where he investigated various aspects of sequential switching circuit theory.

Since 1957, Dr. Unger has been a member of the technical staff of the Bell Telephone Laboratories at Whippany, N. J., where he is doing research in the field of digital systems.

He is a member of Sigma Xi, Eta Kappa Nu, and Tau Beta Pi.

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George Wada (S'54–M'56) was born in Lomita, Calif., on October 18, 1927. After two years of service in the navy, he attended John Muir College, Pasadena, Calif., where he received the A.A. degree. In 1954, he received the B.E.E. degree from California Institute of Technology and in 1955, the M.S. degree from Stanford University. He received the Ph.D. degree in electrical engineering from Stanford University in 1958.

G. WADA

From September, 1954, to June, 1955, he was a recipient of an IBM fellowship at Stanford, and from 1955 to 1958, he held the position of research assistant at the Stanford Electronics Laboratories. At present, he is on the technical staff of the Watkins-Johnson Company, Palo Alto, Calif.

Dr. Wada is a member of Tau Beta Pi and Sigma Xi.

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D. A. Watkins (A'47–M'48–S'49–A'51–SM'55–F'58), was born in Omaha, Neb., on October 23, 1922. He specialized in electrical engineering, receiving the B.S. degree from Iowa State College in 1944, and the M.S. degree from California Institute of Technology where he was a Gerard Swope Fellow from 1950 to 1951.

D. A. WATKINS

In World War II, Dr. Watkins was an army engineer unit commander in the European and Pacific Theaters. He was employed by the Collins Radio Company from 1947 to 1948, and at the Los Alamos Scientific Laboratory from 1948 to 1949. From 1951 to 1953, he was employed by the Hughes Aircraft Company, where he was a member, and then head of the microwave tube section of the research and development laboratories. Since 1949, Dr. Watkins has been engaged in microwave tube research, specializing in traveling-wave tubes and backward-wave oscillators. In March, 1953, he returned to Stanford University, where he is now professor of electrical engineering and Director of the Electron-Devices Laboratories. In 1958, Dr. Watkins also became president of the newly formed Watkins-Johnson Company, Palo Alto, Calif., which is engaged in research, development, and manufacture of electron devices.

Dr. Watkins is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, Pi Mu Epsilon, and Phi Kappa Phi.

# Scanning the TRANSACTIONS

**Stereophonic disk records** and record players are the big news in the home entertainment field this fall. Manufacturers have adopted the so-called 45/45 system of stereophonic recording (described on p. 1686 of this issue), a system in which the record can be played only on a stereophonic player. Considerable interest was aroused at the IRE National Convention last March by the announcement of another system of stereophonic recording that was compatible with existing monaural equipment; that is, the stereophonic record could be played on a standard record player for monaural listening. Compatibility is achieved by converting the signals from the left and right channels into a sum signal and a difference signal. The sum signal, which contains all the significant information presently contained on a standard record, is recorded laterally on the record in the standard fashion. The difference signal, which carries the spatial information essential for stereophony, is recorded as vertical modulation, after first being modified so as not to exceed the limits of vertical mobility of a standard pickup. While the system has not yet been adopted commercially, it offers very interesting possibilities for the future. (P. C. Goldmark, *et al.*, "The Columbia compatible stereophonic record," IRE TRANS. ON AUDIO, March–April, 1958.)

**The latest idea in nuclear radiation monitoring** involves the use of a 19th century invention—the telephone. The advent of the nuclear age with its problems of bomb tests and fallout has led to the necessity for careful radiation monitoring over a large geographical area. This has inspired engineers to devise a simple system whereby a control station operator can obtain radiation data from unattended detector field stations located anywhere within the country simply by "calling up" the station over long-distance telephone circuits and getting a predetermined cycle of readings. (L. Costrell, "Radiation monitoring over long-distance telephone lines and direct field lines," IRE TRANS. ON NUCLEAR SCIENCE, August, 1958.)

**Pocket-size radio receivers,** which have recently become so popular in the home-radio field, are starting to make important inroads in the mobile radio field. During the last few months New York City police on foot patrol in Central Park have been testing the use of pocket receivers with notable success. The list of potential applications is impressive. In addition to police uses, we have military, civil defense, road building, public utilities, construction, telephone paging, and oil, mining and geological survey operations, to name a few. The pocket radio shows great promise of putting new mobility into "mobile" radio. (J. R. Neubauer, "A new arm for vehicular communications," IRE TRANS. ON VEHICULAR COMMUNICATIONS, July, 1958.)

**A fresh look at troubleshooting techniques** is being provided by mathematical studies involving sequential decision theory, information theory, and graph theory. The purpose of these studies is to develop systematic procedures for locating faults as quickly as possible. The key to good troubleshooting techniques is in knowing where to make the initial check and in what sequence to make succeeding checks so as to narrow down the possibilities as rapidly as possible. The best procedure to follow will depend on the relationship between the components to be checked, the time required for the various checks, and whether or not failure probability data for each component is known. Work to date has already provided a rough set of rules which give better results than old cut-and-try guesswork methods. As research continues, it is likely that we will see troubleshooting transformed from a haphazard art to a well-defined science. (A. J. Hoehn and E. Saltz, "Mathematical models for determination of efficient troubleshooting routes," IRE TRANS. ON RELIABILITY AND QUALITY CONTROL, July, 1958.)

**The prospect of atom powered planes** has stimulated a good deal of interest in the possible effects that nuclear radiation might have on the functioning of various kinds of equipment on board the aircraft. In particular, much work has been done recently in exploring radiation damage to semiconductors and other electronic components. It may surprise some to know that one of the problems that arises is that radiation can cause a change in the dielectric constant of the atmosphere in the vicinity of the nuclear reactor, thereby possibly affecting radio transmission and reception. To investigate this possibility, tests were recently conducted near a nuclear reactor to determine whether any significant propagation changes or radio noise generation could be detected in the VHF and microwave regions. Nuclear engineers will be happy to know the tests showed that the radiation shielding they normally provide is also adequate from the standpoint of wave propagation experts. (W. W. Fain, *et al.*, "Electromagnetic noise and propagation observations in the vicinity of a nuclear reactor," IRE TRANS. ON ANTENNAS AND PROPAGATION, July, 1958.)

**Radio tracking of earth satellites** has focused considerable attention on various factors which can alter the character of the satellite's signal as received on earth. As a result, a good deal has been published in the last year on Doppler frequency shifts, Faraday rotation of the polarization plane, and atmospheric refraction. It is interesting to note that still another factor enters the picture, the effects caused by the spin of the satellite. It has been determined that if a satellite spins on an axis that differs appreciably from its axis of symmetry, the transmitted signal is split into three components, one at the carrier frequency and the others at upper and lower sideband frequencies separated from the carrier by the spin frequency. Since a satellite spins at only about two cycles per second, the frequency separation between the components is small. However, the amplitudes can be significant, producing a relatively complicated signal which designers and users of radio tracking equipment should take into account. (J. T. Bolljahn, "Effects of satellite spin on ground-received signal," IRE TRANS. ON ANTENNAS AND PROPAGATION, July, 1958.)

**The solution of polynomial equations** is a tedious chore that arises quite frequently in servomechanisms, communication engineering and aerodynamics work, and in vibration problems in the field of applied mechanics. These solutions can now be obtained with accuracies of up to 0.2 per cent quite easily with an isograph of comparatively simple construction. The equipment involves no more than a series of multitapped transformers, RC phase shifting networks, and cathode followers. The design is based upon the principle of cumulative phase shifting, result in a compact, inexpensive, and portable instrument. It can serve as an aid to large scale computing machinery by isolating roots before further calculations are made, as well as in matrix computations. It could be a valuable adjunct in the design of servomechanisms as well as in the calculation of the transient behavior of linear electrical and mechanical systems. (P. V. Rao, "A novel type of isograph," IRE TRANS. ON ELECTRONIC COMPUTERS, June, 1958.)

**The role of the base station antenna** in vehicular communications comes into the forefront with technical advances in gain-producing structures and more sophisticated systems planning. Improved aperture illumination on a 450-mc gain antenna is obtained by application of a new principle to the classic colinear coaxial array. Novel "suppressor" designs spaced along and enclosing the driven conductor solve the age-old problem of passing the signal on down the conductor with no loss and preventing any of it from being able to radiate an out-of-phase component. The final antenna design provides 10 db gain at 450 mc. Other base station antennas operating at 25–50 mc have been developed in which side mount units make use of the supporting tower structure to shape the pattern to that desired. Many charts are provided to show that in systems planning, one must consider the range pattern provided by the antenna rather than the voltage or power pattern. Antennas with figure eight voltage patterns are shown to provide rectangular area coverage. (M. W. Scheldorf, "New high gain station antenna," and T. J. McMullin, "The end of the line," IRE Trans. on Vehicular Communications, July, 1958.)

**What are the major contributions to logical machine design** and how can an engineer find material of use to him in the design of computers? The question is important because of the increasing use of mathematical logic in the design of computing machine networks and components, and the use of logic machines to help solve problems in logic. The answer is provided by a recently published bibliography of nearly 500 references in the field of logical design of machines. Selections were made with the objective of being useful and stimulatory to the wide variety of scientific persons who have some interest in the subject. An essential feature is the extensive index of significant title words. Each indexed word is given in the complete context of the title in which it occurs. (B. Netherwood, "Logical machine design: A selected bibliography," IRE Trans. on Electronic Computers, June, 1958.)

**Design of active networks** usually stresses methods of obtaining stability when the network operates between the specified source and load impedances. In the design of oscillators, however, the objective is the opposite one of maximizing instability. The latter problem has recently been attacked in the general form of instability optimization of an active network matrix combined with external passive feedback. The results establish a design synthesis procedure for generation of oscillations at any frequency for which the active circuit parameters are known. In particular high frequency transistor oscillators can now be designed analytically instead of by cut-and-try methods. (D. F. Page and A. R. Boothroyd, "Instability in two-post active networks," IRE Trans. on Circuit Theory, June, 1958.)

# Books

### The Solid State for Engineers, by Maurice J. Sinnott

Published (1958) by John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 515 pages+6 index pages+xi pages. Illus. 9¼×6¼. $12.50.

This book is an introduction to the fundamental principles underlying engineering materials. As stated in the preface, it is not a handbook of engineering materials or their use, nor is it a textbook on solid-state physics, but rather a fairly coherent outline of the fundamental properties of a wide range of solid-state materials, tied together by a common basis in atomic structure, crystal structure, chemistry and thermodynamics, and modern physics. There is a logical sequence through the introductory chapters, while later chapters are fairly independent of each other, facilitating the use of this book to gain a rapid introduction to an unfamiliar field.

There are many illustrative examples given (some with painfully complete arithmetic detail) to help give the reader a quantitative feeling for magnitude and relationships. The format and typography are clear, and the illustrations, mostly taken from standard references, are well chosen. There are numerous useful reference tables of physical constants.

On the whole, topics are developed to a reasonably consistent technical level. However, specialists in many of the fields covered may question the choice and relative emphasis of various specific topics. For example, the thermistor is given about six pages—roughly the same as the total discussion of all types of rectifiers (*i.e.*, the same amount of space as the six pages given to the completely inadequate index). The thermistor discussion cited contains several pages of characteristics and applications while the transistor is given no discussion whatsoever of practical characteristics beyond a brief paragraph which includes the somewhat questionable statement that in an *n-p-n* junction transistor: ". . . the collector, shows an enlarged flow of current for a small flow in the . . . emitter." The chapters on mechanical and thermal properties of solids contain no systematic discussion of the problems of strength of materials at extremely high temperatures. Ceramic solids receive no explicit discussion. Organic polymers are given several pages of text, but glasses are not discussed. Half of the chapter on optical properties is allotted to various aspects of luminescence, but without mentioning electroluminescence at all. The chapter on magnetic properties contains a brief section on ferrites, but there is no discussion of square loop materials.

Omissions, of course, are inevitable in a book of this size and scope. Those cited above are not to be considered as a blanket indictment of the book. However they do illustrate that this book is not aimed primarily at the specific need of the electronic engineer, although within its irregular scope, he will find it useful. The author has packed a lot of well-organized basic information into a volume which does not pretend to be a complete solid-state encyclopedia. Furthermore, there are adequate references to the standard literature in each field, where many of the omitted topics are readily accessible.

This book should serve as a useful text for survey courses on materials for upper class undergraduate or first year graduate students in engineering curricula. In addition, the research and development engineer or scientist will find this book very helpful as an easy reading introductory guidebook to some of the unknown foreign territories which lie outside his own particular specialized area of competence.

John S. Saby
Lamp Res Lab.
General Electric Co.
Cleveland, Ohio

### Circuit Analysis of Transmission Lines, by J. L. Stewart

Published (1958) by John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 176 pages+5 appendix pages+4 index pages+xi pages. Illus. 9¼×6¼. $5.50.

Transmission lines are usually covered in a textbook on the broader subject of communication networks. This author has elected to remove this subject and to make it the scope of a separate brief textbook. The result has some of the attributes of a "sampler," treating the more elementary aspects of field theory and networks in their direct relation to transmission lines. The theory is well presented with excellent mathematical support.

The order of presentation has a logical basis. From the wave viewpoint, transient and sinusoidal waves are described, then the transmission problems associated with standing waves caused by reflections. The use of lines as circuit elements is presented with reference to resonant lines and the lumped circuits equivalent to a section of a line. In conclusion, there are given some of the prevalent techniques for measuring the properties of lines, and some applications of the reflection chart.

The author is well known for his recent textbook, "Circuit Theory and Design." The present volume is based on lectures to senior students given at the California Institute of Technology; the author is now teaching at the University of Southern California.

This volume is suitable for a short undergraduate course in transmission lines, especially if it is desired to separate this topic from the more general treatment of communication networks.

H. A. Wheeler
Wheeler Labs.
Great Neck, N. Y.

### Piezoelectricity, by the General Post Office Research Station

Published (1957) by the British Information Services, 45 Rockefeller Plaza, N. Y. 20, N. Y. 369 pages+x pages. Illus. 11×8¾. $13.86 postpaid.

This book contains a series of reports on research carried on from 1945 to 1953 by, or under the guidance of, Rudolf Bechmann. The purpose of the project was the development of synthetic filter crystals to replace quartz or improve on it. The substances studied in detail were all covered in the program carried out for similar purposes at the Bell Telephone Laboratories in the middle 1940's (see W. P. Mason, "Piezoelectric Crystals," D. Van Nostrand Co., Inc., 1950). The piezoelectric and elastic constants of such crystals as dipotassium tartrate and ethylene diamine tartrate in this thorough British work may be regarded as definitive, but they introduce little that is new from an engineering point of view. Neither the American nor the British work has produced any material that can compete with quartz in stability and versatility. Synthetic quartz itself is at present the only practical substitute for natural quartz.

The volume is of value to the research worker in piezoelectric crystals for its detailed development of theory, for descriptions of crystal growth, preparation, and measurement technique, and for a chapter on breaking strength.

Hans Jaffe
Clevite Corp.
Cleveland 8, Ohio

### Nonlinear Control Systems, by R. L. Cosgriff

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 319 pages+2 appendix pages+6 index pages+viii pages. Illus. 9¼×6¼. $9.00.

Notebooks of practicing engineers and a vast periodical literature testify to the importance of nonlinearities in control systems. Few of the standard texts, however, even define the terms "linear" and "nonlinear." When the problems of nonlinearity are discussed, it is generally in a final chapter following a lengthy development of the theory of linear systems.

As the title would indicate, this emphasis is reversed in the new book by Professor Cosgriff. After a brief introductory chapter, two chapters are devoted to a summary of techniques for analyzing linear systems, emphasizing particularly the frequency-response method. The remaining eight chapters, constituting about two-thirds of the book, deal entirely with nonlinear systems.

It should be added immediately that, despite his break with previous books, Cosgriff does not advocate such drastic departures from established pedagogical practices as teaching nonlinear theory to the exclusion of linear theory. The book is used in a second undergraduate course which follows a course on linear systems. Chapters 2 and 3, a skillfully done but highly condensed presentation of linear control theory, are included primarily for review and reference. They are not a substitute for a full book on the same material, and anybody entering the field of feedback control systems for the first time can be advised to study this book and the older texts.

After the introductory and reference matter, the author discusses small-signal and piecewise linearization procedures which permit linear methods to be extended to nonlinear problems. An interesting application of these techniques is made to the analysis and design of function-generating systems, *i.e.*, systems in which the equilibrium output is supposed to be a nonlinear function of the reference input.

The next three chapters concern two much-discussed methods adapted particularly to nonlinear systems. In the first, the phase plane is introduced, isocline construction is explained, and limit cycles are defined and illustrated. Applications are shown to systems containing a relay, nonlinear friction, and backlash. Sinusoidal analysis is treated in the next two chapters. Although the common term "describing function" is not used, the equivalent concept of nonlinear gain is exploited in checking for the presence of limit cycles and calculating the approximate frequency response of nonlinear systems. More attention than usual is given to asymmetrical systems in which a dc component must be considered as well as harmonics of the excitation frequency.

Chapter 9 is devoted to linear equations, typified by Hill's and Mathieu's equations, which have periodic coefficients. Transient solutions of such equations furnish a means for testing the stability of limit cycles. At the end of this chapter, sample-data systems are treated as linear systems with time-varying parameters.

Concluding chapters illustrate the application of statistical methods to nonlinear systems that are subject to random inputs and the introduction of logic circuits as control elements. The latter topic is initiated by a brief discussion of Boolean algebra and switching devices, and it includes a description of a peak-seeking system which might be applicable in optimization problems.

The book is marred by a number of writing or proof-reading lapses. A theorem introduced in connection with modifying function-generating systems seems to depend on the identity

$$\frac{g}{y}[yr - yf(c)] = g[r - f(c)]$$

where $r$ and $c$ are signals, $y$ is a factor, and $f$ and $g$ are evidently nonlinear functions. If $g$ is nonlinear, the equation is not valid. On page 112, stiction is defined as the force needed to initiate motion, Coulomb friction as the force needed to maintain motion; in common usage, Coulomb friction is only one component, independent of velocity, of the force opposing motion. A co-author of the book "Principles of Optimalizing Control Systems" is listed once as Y. T. Lee and later (correctly) as Y. T. Li. And Figure 6-5 is described as showing isoclines and guide lines, but only trajectories appear.

At several points, analog computer solutions are presented to verify a calculation. Conspicuous by its absence, however, is any general discussion of computers—either analog or digital—as tools for the study of nonlinear control systems. There are doubtless many engineers who would argue that computers are the only practical way to handle nonlinear problems and analytical methods are, at best, a means for checking computer solutions of simplified cases or gaining insight into the behavior of nonlinear systems. Nothing is said in support or rebuttal of this view.

All in all, the book can fairly be described as introductory rather than encyclopedic in nature. It does not—and perhaps cannot—reflect the variety of methods and results contained in the periodical literature. Workers in the field will observe that some topics, such as phase-space analysis and design of higher-order systems or the compensation of nonlinear systems, are merely mentioned. The author wisely omits presentation of practical remedies for nonlinear problems in favor of fundamental methods of analysis. To engineers hunting an introduction to the theory of nonlinear control systems, the book can be recommended.

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### Television in Science and Industry, by V. K. Zworykin, E. G. Ramberg, and L. E. Flory

Published (1958) by John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 275 pages+12 appendix pages+9 index pages+xii pages. Illus. 9¼×6. $10.00.

As indicated in the preface, the book as a whole covers "television as an extension of human sight, variously called closed circuit or industrial television to distinguish it from the more specialized broadcast function." It is divided into five chapters, which may be briefly summarized as: 1) historical, 2) fields of application, 3) equipment, 4) status in 1957, and 5) forecast.

It is believed that this book is a significant contribution to the literature of scientific, medical, and biological electronics, a field growing in importance and one which is receiving more and more attention from scientists and medical men. Approximately 20 per cent of the material deals with television applications to microscopy, particle counting and identification, radiology, nuclear research, etc. The appendix is "Comparison of Performance Limits of Vidicon and Flying-Spot Television Microscopes in the Ultraviolet." It is in these areas that this book is outstanding and presents a fine treatment of interesting and pertinent information not generally available heretofore.

The balance of the text varies in degree of complexity and in the amount of detail given to different facets of the closed circuit TV field. As a result, the type of readership expected is not clearly evident. The preface states: "Although the presentation is essentially self-contained and does not require more of the reader than an elementary knowledge of electronics circuits, copious references are given. . . ." On the contrary, much of the information presented, particularly in Chapter 3, seems to presume a rather intimate knowledge of television practices. For example, concepts and terms such as synchronization, aperture correction, Genlock, Schmidt optics, equilibrium potential, black level, shunt peaking, 2870°K tungsten source, highlight, etc., are discussed or used with little or no explanation. For many readers, this would require frequent use of reference material, inasmuch as there is no glossary of terms.

Industrial television is growing rapidly, and it is understandable that some 1956–1957 equipment and techniques are not mentioned. Examples are the GPL Model PD152, the DuMont Model 100, the Diamond Power Model 500, the Jerrold distribution system using multiplexed tone signals for remote control, and the Scanoscope. There is also some understandable emphasis on the work and the equipment of one manufacturer. Nevertheless, at least half of the suppliers of industrial television equipment are listed, including a good number of foreign concerns.

The book is well written; the illustrations are plentiful and clear; a number of more general references would have been appropriate; and the index might have been more complete. Certain minor discrepancies are noted, but do not detract from the total presentation. For example, in television terminology, "transfer characteristic" is generally preferred to "gamma" (page 56); and "depth of focus" is used (page 64) where "depth of field" is meant.

In summary, this reviewer believes that "Television in Science and Industry" will be a valuable reference for those with some specific technical knowledge of the television field. In the over-all aspect, the coverage and treatment are conventional and well done; the material in Chapter 4 and the discussions of medical and scientific applications are excellent.

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### Principles of Noise, by J. J. Freeman

Published (1958) by John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 292 pages+3 appendix pages+3 index pages+x pages. Illus. 9¼×6¼. $9.25.

In the words of the author's preface, this book "... aims to acquaint the student with enough of the principles, facts, and techniques used in noise analysis to take him to the level where he can read the literature with enough ease to use it as a professional tool." In addition, the author states, "Because of the inhomogeneous make-up of most graduate classes, I have tried to make the text self-contained so that engineering maturity rather than specific course work is the prerequisite for the course."

In line with the objective of being self-contained, the book includes a chapter of Fourier series and integrals and another on the principles of probability. Following a third chapter on the nature of stationary random processes, the book then takes up the physical sources of noise. This section treats not only resistor noise but also thermionic sources such as temperature and space charge limited diodes, triodes, and pentodes. The author then goes into the various representations of the physical sources including a noise calculus and a chapter on the concept of noise figure.

Detection theory is introduced in a chapter entitled, "The Measurement of a Direct Voltage." After a chapter on the nature of Gaussian random processes, the subject is then further developed in the chapter "The Detection of Alternating Waveforms." Finally, the last chapter entitled "Target Noise" introduces the student to the type of problem in which the signal as well as the disturbance must be described in statistical terms.

To this reviewer, it would appear that there is some question as to the wisdom of trying to teach a course on noise theory without requiring a prior grounding in probability theory and the principles of Fourier analysis. The introductory chapters can treat these subjects only sketchily at best. As a result of this, the balance of the book is somewhat more cumbersome and involved than would be necessary if the author could make freer use of more elegant concepts. It would also appear that there is some danger that a student completing this course would feel he now knows noise theory when in fact his knowledge is still quite superficial.

Despite the above comments, it is felt that, with a competent teacher, a course based on this book can readily achieve the aims stated in the author's preface. The book is readable and well provided with problems designed to develop the skill of the student. We would suggest that the teacher using this book should take special steps to acquaint students with the literature. Such a procedure would insure that the author's aims are not only achieved but utilized.

In many fields of electronics, it is becoming necessary for engineers to possess a well-developed knowledge of noise theory. It seldom happens, however, that such a need is not coupled with a need for a well-developed knowledge of Fourier and Laplace techniques and at least an elementary knowledge of probability. We would prefer therefore, to see noise theory taught as part of a systematic sequence. If this is done, it is believed that a different type of book would be preferable. On the other hand, where it is necessary that the course be self-contained, Dr. Freeman's book can be the basis for a worthwhile course.

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### Introduction to Electromagnetic Fields, by Samuel Seely

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 299 pages+4 index pages+xi pages+2 bibliography pages+2 appendix pages. Illus. 9¼×6¼. $8.50.

This is a well-prepared, excellently presented and adequately illustrated new text by Dr. Seely which is certainly needed today to bridge a sizable gap of long standing in this most basic and classical field. This gap has existed between the more elementary college texts on the subject and those intended primarily for graduate study. Dr. Seely's book, I would judge, will become an outstanding text for sophomore and junior year courses to introduce engineering students in engineering schools to the fundamentals of electromagnetic field theory and Maxwell's equations.

Dr. Seely introduces and presents his material in logical order and in increasing complexity of field concepts as the book progresses. The utilization of vector mathematics and vector notation is brought in early, along with the physical concepts of various types of fields and interesting engineering applications. Throughout, emphasis is around the electrical charge theory, with considerations of charges of static nature, in uniform motion and in accelerated motion.

Initially, current flows in electric fields in multidimensional conductors are covered, including field intensity; potential difference; potential gradient; Ohm's, Kirchhoff's and Joule's laws; field mapping; etc. Static fields and charges involving Coulomb's and Gauss' laws, Poisson and Laplace equations follow. Conductors, capacitors, capacitance, and dielectrics are discussed in a very practical manner along with energy and mechanical stresses in electric fields.

Electric charges in motion, current flow in metallic conductors, magnetic fields in free space, self and mutual inductance, etc. are then presented and illustrated. Magnetic circuits and the effects of magnetic materials, domain theory and magnetization characteristics are introduced, with the basic laws and theories of electromagnetic induction.

Energy and mechanical forces in magnetic fields are very excellently presented, with practical problems and concepts. This leads to Maxwell's equations and the important phenomena of electromagnetic wave motion and radiation, and Poynting's theorem and vectors. The treatment of energy and magnetic fields is covered in a most extensive and clear-cut manner.

In summary, I feel that Dr. Seely's new book will prove to be a most worthwhile addition to outstanding college texts and a worthy contribution to engineering literature. It should provide a basis for strong engineering undergraduate courses enabling engineering students to obtain a sound background in basic electricity and magnetism.

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### Le Calcul Analogique par Courants Continus, by Danloux Dumesnils

Published (1958) by Dunod, 92 rue Bonaparte, Paris 6, France. 241 pages+3 index pages+xiii pages +2 bibliography pages+11 appendix pages. 156 figures. 9¾×6¼. 2.850 fr.

An unfortunate quality of too many textbooks is their willingness to sacrifice readability to pedantic thoroughness. Professor Dumesnils has written a textbook that is a refreshing exception in that respect.

The author is a professor at the École Nationale Supérieure de l'Aeronautique in

France, and the book is in essence a text for the course in analog computation given to students of that school.

The keynote of the book is best stated by the author himself in the preface: "... only a little science, and much practice." The material is presented clearly and with notable logic. The illustrative problems and exercises, while few in number, have the great virtue of being clearly stated and solved in illuminating and thorough detail.

The first three chapters cover the differentiation of the various types of analog instruments, their functional and organic elements, the concept of precision, and the different means of output. Chapter 4 discusses the analog solutions of linear algebraic systems. In contrast with other authors on the subject, Professor Dumesnils draws a sharp demarcation line between his discussion of the solutions to linear and nonlinear systems, and this is all to the good. A chapter is devoted to the description of analog computers and simulators currently on the market. The final chapter presents a good survey of the types and extent of the applications with which analog techniques can be used.

The major criticism one is forced to direct at the book stems from the author's fanatic preoccupation with language, which often borders on a chauvinism unworthy of the universality of science. The text of the book is literally riddled with asides, comments, and footnotes which haggle over established definitions, deplore americanisms and anglicisms, etc. While a few of the criticisms of loose terminology are quite valid, the net effect of the author's *idée fixe* is to bring confusion to the impact of key definitions—and also to generate irritation, at least with this reviewer.

On the whole, however, the book is well suited to serve as an introductory textbook to the analog field. In the hands of the engineer, it should provide an equally valuable introduction into the nature and potential of an art which the engineer cannot afford to ignore.

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## RECENT BOOKS

Banner, E. H. W. *Electronic Measuring Instruments*. The Macmillan Co., 60 Fifth Ave., N. Y. 11, N. Y. $7.95.

Broadbent, D. E. *Perception and Communication*. Pergamon Press, 122 E. 55 St., N.Y. 22, N. Y. $8.50.

Churchill, Ruel V. *Operational Mathematics. Second Edition*. McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $7.00.

Cunningham, W. J. *Introduction to Nonlinear Analysis*. McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $9.50.

Davis, Martin. *Computability and Unsolvability*. McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $7.50.

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Magner, Thomas F. *Manual of Scientific Russian*. Burgess Publishing Co., 426 So. 6 St., Minneapolis 15, Minn. $4.00, unbound, $4.60, spiral-bound.

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Spencer, K. J. *High Fidelity: A Bibliography of Sound Reproduction*. Iota Services Ltd., 38 Farringdon St., London, E.C. 4, England. $4.20.

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# Abstracts of IRE TRANSACTIONS

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## Antennas and Propagation

### Vol. AP-6, No. 3, July, 1958

**Maximum Gain of a Line Source Antenna if the Distribution Function is a Finite Fourier Series**—L. Solymar (p. 215)

If the highest permitted harmonics of the distribution function (this is the quantity of interest in practical application) and the supergain ratio are given, what is the maximum attainable gain? In this paper this optimum problem is solved through the introduction of $n$ dimensional vectors and tensors and the result is obtained in closed form. For the case of two harmonics, numerical results are given. It is concluded that a small improvement in the specific gain is accompanied by a large change in the supergain ratio. The examination of the maximum of the specific gain, without auxiliary condition, leads to the conclusion that the addition of every harmonic increases the value of specific gain, but that the improvement is negligibly small until the number of harmonics becomes greater than the size of the aperture in wavelength. Using the method developed in this paper it is possible for any finite number of harmonics to calculate the optimum distribution function, but the computations become very lengthy as the number of harmonics increases.

**On the Gain and Beamwidth of Directional Antennas**—Roger F. Harrington (p. 219)

A formula is given for the maximum gain of a class of antennas having fields expressible as a finite number of spherical wave functions. This maximum gain can be achieved for arbitrarily polarized radiation fields, and it can be related to antenna size by requiring the near fields to be small in magnitude. Also, the radiation field is in the form of a polynomial, so that patterns optimum in the Tchebycheff sense can be defined. Formulas for the relationship of beamwidth to sidelobe level are given.

**Evaluating the Impedance Broadbanding Potential of Antennas**—A. Vassiliadis and R. L. Tanner (p. 226)

One of the principal concerns of the aircraft antenna designer is to determine whether an antenna having some known terminal impedance characteristics can be compensated to meet a specified, voltage standing-wave ratio (VSWR)-bandwidth relation. Alternatively, the problem may be to select from among possible antenna configurations that one which possesses the greatest impedance broadbanding potential.

In this paper the problem is examined by means of modern circuit theory. Antenna impedances are approximated by rational algebraic fractions and the impedances represented by these functions are treated analytically to determine the VSWR-bandwidth relationship which may be obtained by optimum compensation. The functions that can be considered by the techniques developed are sufficiently complex to adequately represent the basic impedance characteristics obtained with typical airborne flush-mounted antennas over a frequency range that causes the dimensions of the antenna to vary between a small fraction of a wavelength and approximately a wavelength. Examples are given.

**Methods of Reducing Chromatic Aberration in Metal-Plate Microwave Lenses**—Edward K. Proctor (p. 231)

Microwave lenses of the waveguide type are subject to a pronounced degree of chromatic aberration because of the inherent dispersion of the waveguides. However, this aberration can be substantially eliminated over an appreciable bandwidth by making the lens of slot-loaded ridged waveguides with special properties. This type of lens design makes it possible to achieve additional benefits as well, such as improved scanning capability and elimination of discontinuities in the surfaces at the junction of adjacent "zones" or "steps." The ridged waveguides are periodically loaded by means of transverse slots in the ridges. The ridges may be relatively wide and hollow, or quite thin and solid. Additional desirable properties are obtainable by placing a relatively small strip of dielectric material above the ridge. Experimental data on the propagation characteristics of several of these structures and on the effect of varying such parameters as ridge height, slot width, slot depth, slot spacing, frequency, and size of dielectric strip are given.

An analysis of the phase errors which result from changes in the operating frequency shows that the aberrations may conveniently be separated into one type in which the phase front from each zone of the lens is distorted, and a second independent type in which the desired phase relationship between the zones is destroyed. Methods of eliminating either or both of these types of aberration by suitable design of the ridged waveguides are described. In addition, it is shown how the ridged waveguides can conveniently be used to achieve "zoning" or "stepping" by changing the effective index of refraction, thereby eliminating discontinuities in the lens surfaces and avoiding the undesirable diffraction which would otherwise occur at the boundaries between adjacent zones. The superiority of this type of lens structure in wide-angle scanning applications is also discussed.

Numerical examples which illustrate the advantages of the loaded ridged waveguide lens are included.

**Corrective Line Sources for Paraboloids**—C. J. Sletten, R. B. Mack, W. G. Mavroides, and H. M. Johanson (p. 239)

By applying optical laws and ray tracing techniques to paraboloidal reflectors, it has been possible to derive the focusing and phasing criteria for obtaining wide angle performance of a paraboloidal microwave antenna system. Although this optics approach represents an approximation to the exact solutions, the experimental results indicate it is satisfactory for practical uses.

The analysis indicates the sections of the paraboloidal reflecting surface best suited to line source correction. The reflector peripheral contour which tends to minimize sidelobes has been indicated.

Two types of midpoint correctors are discussed. These will produce beams fanned in the elevation plane and well focused in the azimuth plane. Experimental results are presented from a midpoint corrector covering 60 degrees in elevation while maintaining well focused azimuth patterns over the entire elevation interval.

Several pencil beams may be produced using one reflector by placing ridge line correctors at the appropriate angles on the focusing surfaces.

**Antenna Evaluation Methods**—W. S. Lucke (p. 251)

Shannon's formula for channel capacity in terms of bandwidth and signal-to-noise ratio is used in a proposed method of antenna evaluation as a weighting function for averaging antenna patterns and impedances over space and frequency. This method is particularly applicable to situations where antennas with widely different characteristics are being compared for similar applications over relatively large bandwidths in which the characteristics of each antenna are subject to wide variation. The evaluation method based upon the Shannon formula is compared with others such as the "antenna-system-efficiency" and "minimum-level" methods.

**Performance Evaluation of HF Aircraft Antenna Systems**—Ernest J. Moore (p. 254)

Many antennas, especially for aircraft application, must radiate into large sectors and operate over wide bands of frequency. At the same time, means of pattern control are often limited. In order to evaluate the performance of such antennas, several antenna-rating schemes have been proposed in the past. This paper is concerned with the evaluation of HF aircraft antennas used for long-range voice ground-to-air and air-to-ground communications. The different antenna evaluation methods are compared theoretically for consistency among themselves. It is shown that they all lead to essentially identical relative ratings of different antennas used on the same aircraft. Furthermore, these ratings can be related to articulation scores, operationally the most significant parameter of voice-communication circuits. Since all the rating schemes investigated lead to about the same results, the simplest of these, namely the radiation pattern efficiency, appears to be the most suitable measure of effectiveness of HF aircraft antennas. The conclusions reached were verified through computations on radiation patterns obtained from model measurements.

**Effects of Satellite Spin on Ground-Received Signal**—J. T. Bolljahn (p. 260)

This report presents an analysis of those characteristics of the radio signal received on the ground from an artificial earth satellite which are caused by satellite spin. It is shown that if the spin axis of the satellite does not coincide with the axis of symmetry of the satellite antenna system, a CW transmitted signal will be split into three closely spaced spectral components in a manner similar to the Zeeman effect in atomic spectra.

The relative amplitudes of the three spectral components are calculated for various combinations of satellite antenna type, ground antenna type, antenna observation angle, and angle between the spin axis and antenna symmetry axis of the satellite, and the significance of these results is discussed.

**Applications of Operational Calculus to Ground-Wave Propagation, Particularly for Long Waves**—H. Bremmer (p. 267).

All results of the approximative diffraction theory dealing with the propagation of radio waves around a smooth spherical earth (surrounded by a homogeneous atmosphere) can be derived from a one-dimensional integral equation originally discussed by Hufford. This equation can be solved in terms of operational calculus which leads, first of all, to the well-known residue series. In this treatment the Sommerfeld theory for a flat earth appears at once as a limiting case; moreover, analytic expressions for correction terms accounting for the finite value of the earth's radius are easily determined. Finally, the equation in question can also be used for the extension to inhomogeneous soil conditions, without neglecting the earth's curvature.

**On the Measurement of Ground Conductivity at VLF**—J. R. Wait and A. M. Conda (p. 273)

The applicability of the four electrode methods of measuring ground conductivity at very low radio frequencies is discussed. The general theory is extended to include anisotropy in the substrata. In view of the spurious coupling between the current and potential line in conventional configurations, an alternative array is proposed which is arranged so that the inductive coupling is zero. A number of charts are computed which facilitate the interpretation of the measured or apparent conductivity in terms of a two-layer earth.

**Altitude Variation of Field Strength for Vertically Polarized Low and Broadcast Frequency Radiation**—J. R. McGonegal, J. W. Savage, and C. A. Zielinski (p. 278)

Height-gain calculations have been made using Norton's formulas at low and broadcast frequencies in cases where the values of numerical distance and numerical height do not permit the use of simplified graphical methods. Field strength measurements at various altitudes showed good agreement with the calculated values. The airborne field strength measuring installation and the manner of its use are described.

**Simplified Method for Computing Knife Edge Diffraction in the Shadow Region**—L. J. Anderson and L. G. Trolese (p. 281)

A simplified method of computing knife edge diffraction in the shadow region is presented which is applicable to most obstacle gain paths, that is, paths with a dominant mountain obstacle. The method has been worked out for 1) the four-ray model—specular reflection on each side of the obstacle, 2) the two-ray model—reflection on one side only, and 3) the single-ray model—no reflection on either side. The obstacle can be at any location along the path. The accuracy is within 2 db for path geometries such that the usual diffraction parameter $v$ is greater than 1 and the two terminal heights are less than the obstacle height. Curves which further simplify the computation procedure are presented.

**Electromagnetic Noise and Propagation Observations in the Vicinity of a Nuclear Reactor**—W. W. Fain, C. M. Crain, and W. C. Duesterhoeft (p. 286)

Electromagnetic noise and propagation measurements have been made in the vicinity of a nuclear reactor to determine whether reactor radiation would affect $X$-band and VHF signals. No radiation effects were observed. A 15-foot $X$-band propagation path was instrumented for observation of attenuation and phase changes. The over-all sensitivity was one part in $10^5$ or 10 $N$ units average over the path. Reactor radiation over the path was greater than $10^4$ roentgen per hour. No significant phase or attenuation change was observed as reactor power level varied. A 12-db noise figure, 8-mc bandwidth, 18-inch dish antenna, $X$-band receiving system, and a 12-db noise figure, 4-mc bandwidth, tuned dipole antenna, 94-mc receiving system were pointed at the reactor from approximately 18 feet. No significant electromagnetic noise generated by reactor radiation was observed with these receiving systems.

**The Correlation Between the Electric Field at a Great Distance and a New Radio-Meteorological Parameter**—Pierre Misme (p. 289)

The daily variations of hourly median 1046-mc transmission loss, recorded over a 370-km propagation path, are found to be correlated with a new meteorological parameter that combines the thermodynamic stability of the atmosphere and the "useful gradient" of the radio refractive index. The thermodynamic stability is evaluated from the area contained between the observed temperature distribution with height and the pseudo-adiabatic temperature lapse, while the useful gradient of the refractive index is derived from ray tracing considerations, and is weighted towards the initial gradient.

**Communications**

**Comparison of Some Experimental Terrain Diffraction Losses with Predictions Based on Rice's Theory for Diffraction by a Parabolic Cylinder**—J. H. Crysdale (p. 293)

**The Equivalence of Electric and Magnetic Sources**—Paul E. Mayes (p. 295)

**The Effect of the Size of a Two-Dimensional Array on Second-Order Beams**—G. C. McCormick (p. 297)

**Some Observations on Scattering by Turbulent Inhomogeneities**—S. Stein (p. 299)

**Scalar-Vector Analog of Green's Theorem**—H. Unz (p. 300)

**Radiation Patterns of a Spherical Luneberg Lens with Simple Feeds**—Robert E. Webster (p. 301)

**Abstracts of Papers from the IRE-URSI Symposium** (p. 303)

**Correction** (p. 320)

**Contributors** (p. 321)

## Audio

### Vol. AU-6, No. 2, March–April, 1958

**PGA News** (p. 23)

**Columbia Compatible Stereophonic Record**—P. C. Goldmark, B. B. Bauer, and W. S. Bachman (p. 25)

A "compatible" stereophonic record is one which will reproduce full stereophonic sound when played on a stereophonic phonograph and will be indistinguishable from an LP record when played on a monaural phonograph. Such a record may be obtained by recording the sum signal $S=L+R$ as lateral modulation and the difference signal $D=L-R$ as vertical modulation, and suitably modifying $D$ so that the tracking possibilities of monaural pickups are not exceeded.

**Modulation Noise in Magnetic Tape Recordings**—R. Lee Price (p. 29)

Modulation noise remains as a major limitation on the dynamic signal-to-noise ratio obtainable in a magnetic recording system. The sources of modulation noise in magnetic tape recordings have been investigated by reducing to the smallest possible value the inherent noise of the recording and playback equipment used in the tests. Possible causes of modulation noise are then independently introduced and their effects measured. The results of these measurements indicate that when recording and reproducing equipment is properly adjusted, the major source of modulation noise is spurious amplitude modulation of the recorded signal by variations in the physical and magnetic properties of the recording tape. The amount of this modulation noise is found to increase above the value obtained with a dc signal, in proportion to the recorded signal frequency. Recommendations are made for measurement of amplitude modulation noise as a check on tape quality and on those adjustments which affect amplitude modulation noise. This measurement is in addition to the measurement of frequency modulation noise commonly known as "flutter."

**Transistor Nonlinearity—Dependence on Emitter Bias Current in *P-N-P* Alloy Junction Transistors**—D. R. Fewer (p. 41)

A method of calculating the nonlinear behavior of class-A common emitter transistor amplifiers from linear small signal measurements is given. Experimental results, obtained with a 500-milliwatt *p-n-p* alloy junction transistor, show the second and third harmonic distortion as a function of emitter bias current and driving source resistance. Distortion, calculated from small signal measurements, is shown for comparison.

**Contributors** (p. 45)

## Circuit Theory

### Vol. CT-5, No. 2, June, 1958

**Abstracts** (p. 88)

**Necessary Conditions on the Matrix of an RC Grounded Quadripole**—P. Slepian and L. Weinberg (p. 89)

Conjectures of Lucal and Darlington on the synthesis of the matrix of an RC three-terminal network are examined in this paper. Suppose each of the three open-circuit impedances, $z_{11}(s)$, $z_{12}(s)$, and $z_{22}(s)$, is specified as the quotient of two relatively prime polynomials; each is then rewritten as a rational fraction with the polynomial $W(s)$ as denominator, where $W(s)$ is the least common multiple of the three denominators. Lucal and Boxall conjecture that in this representation every numerator coefficient of each impedance is non-negative, and in addition, each coefficient in the numerator of $z_{12}(s)$ does not exceed the corresponding coefficient in the numerator of $z_{11}(s)$ and $z_{22}(s)$. It is observed that these two propositions are equivalent necessary conditions, and a counter example to the first proposition is exhibited. Darlington conjectures that any realizable RC three-terminal network can be synthesized by the $\pi$-$T$ decomposition method described by Lucal. This counter example casts some light on Darlington's conjecture.

An examination of the above counterexample suggests another condition which may be necessary. It is shown that if the number of nodes of the network does not exceed five, this new condition is indeed necessary; however, it is not known whether it remains valid when the number of nodes exceeds five. In the discussion of these matters a new proof is exhibited of the fact that each root of the determinant of the nodal admittance matrix is a nonpositive real number.

**Evaluation of Transistor Neutralization Networks**—A. J. Cote, Jr. (p. 95)

The neutralization technique selected for use with transistor IF amplifiers will have a considerable effect upon the gain and stability of the amplifier. Attention is concentrated here upon the matrix methods of neutralization which unilateralize the transistor.

The matrix parameters of the unilateralized device are derived for each of the four types of unilateralization—$z$, $y$, $h$, and $g$. These are expressed in terms of the transistor two-port parameters and the elements of the neutralizing network. The influence of the network on the driving point immittances, maximum transducer gain, and stability can then be considered. (Unilateralization *does not* necessarily insure unconditional stability.) The effects of nonideal transformers used for the $z$ and $y$ types of neutralization are evaluated.

Applications of these equations, over the frequency range from 30 to 80 mc, using measured parameters of the type 3N25 tetrode, are discussed.

**Synthesis of a Class of Strip-Line Filters**—H. Ozaki and J. Ishii (p. 104)

This paper describes a design theory for a class of strip-line filters on an insertion loss basis. The important part of the paper is the equivalent transformations showing the close correspondence between lumped and coupled-line distributed parameter circuits. An introduction is provided for clarification. Line type, low-pass ladder, high-pass ladder, and band-pass ladder type filters are realized in coupled strip-lines. Their physical configurations are depicted. Finally a development is given of characteristic-immittance formulas.

**On the Synthesis of the Crystal-Capacitor Lattice-Filter with Symmetrical Insertion Loss Characteristics**—T. E. O'Meara (p. 110)

A general synthesis procedure is described for the very narrow-bandwidth lattice crystal filter. Specifically, it has been shown that equivalent low-pass insertion functions for all (almost) symmetrical insertion functions of lattice, crystal-capacitor filters may be expressed by the ratio of two polynomials of even degree in complex frequency.

Starting with two such polynomials corresponding to the desired insertion function, it is shown how a set of corresponding crystal constants may be found.

**Some Fundamental Considerations on Active Four-Terminal Linear Networks**—Masamitu Kawakami (p. 115)

This paper describes some fundamental properties of active four-terminal linear networks.

Some considerations are given on elementary active four-terminal networks, which are defined as networks having more than two zero elements out of four in their fundamental matrices. These four-terminal networks are classified according to their properties and their relation to each other. Some examples are given in which such networks are applicable; the networks can also be used to represent vacuum tube or transistor circuits.

**On Evaluation of the Graph Trees and the Driving Point Admittance**—N. Nakagawa (p. 122)

The evaluation of characteristic numbers for trees has been done either by drawing the graph trees or by settng up a "primitive node-pair connection matrix." In this paper a new algorithm called the foldant is proposed. This is an algebraic method equivalent to the drawing of the graph trees.

When a node, say node $n$, is superposed upon another node, say node 1, any branch $ni$, where $i$ is any third node, is now parallel to the branch $li$. This geometrical transformation can be described by the algorithm of the foldant.

As a direct application, Maxwell's rule of the driving point admittance which is described in the Appendix of his classic book, can be rewritten in terms of the foldant. Thus, as far as the computation of driving point admittance is concerned, it is no longer necessary to write down a set of node or loop equations nor to remember the lengthy statement of Maxwell's original rule.

In this paper, pertinent theorems are given, together with proofs. Examples are given to clarify the method of computation.

**Flatness and Symmetric Low-Pass Lossless Filters**—J. L. Stewart (p. 128)

Subsequent to a review of flat transfer functions and maximally flat functions with transmission zeros on one or both of the two axes in particular, characteristics of lossless symmetric networks with equal resistance terminations are given. Several theorems pertaining to the order of flatness for such filters are presented and specific design examples are given. The theorems, along with the representative examples, provide a basis for development of an extensive approximate graphical cascading design technique which gives better results than image-matching methods for unbalanced filters. In the method, control of phase is possible while maintaining known flat gain characteristics. Also, existence of and design methods for approximately all-pass phase-equalizing networks which allow for shunt capacitance are demonstrated.

**Instability in Two-Port Active Networks**—D. F. Page and A. R. Boothroyd (p. 133)

The general bilateral, two-port active network, defined by its $y$, $h$, $z$, or $g$ parameters, is treated for arbitrary terminations and external feedback with and without transformers. Stability considerations necessary for amplifier design are first discussed. These considerations are then extended to the design of instability, and the concept of maximum potential instability with external feedback is introduced. This is shown to be related to Mason's invariant $U$ function.

Simple small-signal oscillation conditions are obtained analytically in terms of the general active element parameters, from which practical oscillator circuits are easily designed by the substitution of transistor or vacuum-tube parameters. Circuits using feedback with and without transformers are considered.

The use of these results is indicated for possible studies of large-signal oscillation, and for the stabilization of oscillation frequency and amplitude.

**Corrections** (p. 139)

**Abstracts of Articles on Circuit Theory** (p. 140)

**Correspondence** (p. 142)

**PGCT News** (p. 148)

## Electronic Computers

## Vol. EC-7, No. 2, June, 1958

**Nonlinear Transfer Functions with Thyrite**—L. D. Kovach and W. Comley (p. 91)

Since the publication of a previous paper the uses of Thyrite in the synthesis of nonlinear transfer functions in analog computing have been greatly expanded. Moreover, new and considerably improved methods of Thyrite selection and matching have been developed.

The present paper shows how rational exponents can be represented. Functions of the form $y=kx^n$, with $1/\delta \leq n \leq 6$ are readily obtained. Circuit configurations generating the functions

$$1-\left(\frac{2x}{\pi}\right)^{1.74} \text{ and } 1-\left[\frac{2}{\pi}\left(x-\frac{\pi}{2}\right)\right]^{1.74}$$

which provide excellent approximations to the cosine and sine functions, respectively, are given, and an improved quarter-square multiplier using Thyrite squaring is discussed.

A study was also made of the physical factors influencing the performance and accuracy of Thyrite and quantitative experimental data regarding these factors are presented.

**A Novel Type of Isograph (Algebraic Equation Solver)**—P. Venkata Rao (p. 97)

Polynomial equations occur quite often in physical and mathematical problems and require an exact solution. Several problems in control engineering, aerodynamics, and many other fields require the formulation and exact solution of algebraic equations of quite a high order. In the past, several mechanical and electrical machines for the determination of the roots of polynomials have been developed, but all of them suffer from the serious disadvantage that they are very expensive and are incapable of high accuracy and rapidity of operation.

This paper describes the development, design, and construction of an inexpensive and portable isograph which is capable of locating the roots of a polynomial with fairly high accuracy. This isograph can serve as a valuable aid to large-scale computing machinery, for which the roots of a polynomial must be isolated before further calculations can be performed. It can also serve as a very useful adjunct to other mathematical processes such as complementary solution of differential equations, determination of latent roots of a matrix, and similar other applications.

It is hoped that this inexpensive and portable instrument will prove extremely useful in the design of servosystems and in other fields where the problem may be presented as a polynomial and that theoretical studies of engineering problems will be greatly augmented by its use.

**Logically Micro-Programmed Computers**—John V. Blankenbaker (p. 103)

Extremely simple digital computers exploiting the concepts of simulation and micro-programming are described. Logical rather than arithmetic micro-programming operations are employed for generality and greater simplicity. The resulting class of computers can duplicate the behavior of any finite state digital computer except in solution time. Also, design techniques are given for computers employing only multiple-bit time delays.

**Analytical Design of Resistor-Coupled Transistor Logical Circuits**—M. W. Marcovitz and E. Seif (p. 109)

The object of this paper is to analyze and to develop design procedures for a resistor-coupled transistor circuit used in the mechanization of logical operations. The basic circuit consists of *one* transistor and a number of resistors. This circuit performs the OR function followed by the NOT function or the AND function followed by the NOT function. With these compound functions mechanized it is possible to build any logical system.

The first requirement for operation of this circuit is that the transistor must be saturated if one or more inputs are low. The second requirement is that the transistor must be cut off if all of the inputs are high. A "worst case" analysis is performed for each of these requirements.

Three types of solutions are described and discussed: general purpose, intermediate (flexible), and special purpose. The general purpose design uses one standard stage for the mechanization of an entire logical system. The special purpose design is tailored to fit a complete logical system. If any logical change is made, a large part of the circuitry must be redesigned. An intermediate (flexible) design uses different stage designs, having different numbers of inputs and outputs.

Procedures are developed for the design of the general purpose system in two ways: hand computation with a slide rule; computation on a small digital computer (Burroughs E101). Procedures are developed for the design of the intermediate flexible system using hand computation. Examples of the design procedures are shown and optimized for minimum required transistor base current. Circuits were constructed and tested to verify these design procedures.

**On the Analysis of Sequential Machines**—R. G. Gillespie and D. D. Aufenkamp (p. 119)

In this paper we indicate briefly how the methods of the algebraic solution of Markov chains with constant transition probabilities apply to the analysis of sequential machines. Mealy's model of a sequential machine is assumed. A stochastic matrix is associated with each such machine to provide a starting point for the analysis. "Closed" sets of states are then characterized, for example, by the appropriate theorems about Markov chains. A technique is formulated for reducing the connection matrix of any sequential machine to a canonical form.

**Correction** (p. 122)

**Symposium on Computers in Simulation, Data Reduction, and Control**

**Digital Computers in Continuous Control Systems**—Edward L. Braun (p. 123)

The use of digital computers in continuous control systems is discussed. A comparison is made of the two major types of digital machines, namely the GP (general purpose) and the DDA (digital differential analyzer), and characteristic features of each are considered. Certain advantages and limitations of each type are described, together with their indicated areas of application. Methods of processing input data from analog and digital sensing elements are described, as well as means of supplying control signals to output servos.

**Computers in Process Industry Control**—William F. Gunning (p. 129)

Successful inclusion of a digital computer in the real-time control loop of an industrial fluid process plant is dependent on 3 practical steps: 1) the formulation of adequate mathematical models, 2) the development of satisfactory data acquisition techniques, and 3) the proof of sufficient reliability. Examples are taken from the petroleum industry.

**Aspects of Real-Time Simulation**—Walter F. Bauer (p. 134)

Present-day digital computers are too slow for the comprehensive real-time simulation of complex electronic systems such as those involving guided missiles. Computers appearing 2–3 years hence will be sufficiently fast for these applications. There is and will continue to be fertile application fields for analog-digital computer combinations. An existing large-scale (Univac Scientific 1103A-Epsco converter—Electronic Associates) analog-digital system is described. System design and specifications are discussed which relate to real-time speeds, necessary accuracies, digital computer programming, and synchronizing the digital computer with the remaining system components. Techniques for exploiting each computer's advantages are mentioned. Applications in the guided missile field and in other fields are discussed.

**Digital Information Processing for Machine-Tool Control**—Alfred K. Susskind (p. 136)

Flexibility, accuracy, elimination of manual skill, and greater work potential result from the addition of digital data processing to machine-tool control. Several special-purpose digital computers for machine-tool control have now been developed. These perform only simple computational tasks. The more sophisticated tasks require the addition of general-purpose large-scale computers. This combination, while only partially explored, appears very promising. It should lead not only to improvements in translating a part design into the finished piece, but should ultimately assist in the design procedure.

**Realization of Randomly Timed Computer Input and Output by Means of an Interrupt Feature**—L. R. Turner and J. H. Rawlings (p. 141)

The Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics is assigned the primary task of research into the basic problems of the design and operation of aircraft power plants. Since World War II this has primarily meant research in the field of jet and turbine engines.

Although these engine types are simple in concept, it was quickly realized that they could not be developed adequately by research on small-scale models. It has been necessary to build large facilities in which research could be conducted under conditions approximating those expected of actual flight.

With new facilities under construction or being planned, it became clear in the late 1940's that only some form of mechanization could cope with the growing problem of data-processing. The resulting studies led to a plan in early 1950 for the construction of a data-recording system aimed toward digital data-processing techniques.

In January, 1952, the first model of an automatic digital pressure recorder with mechanized, manually-controlled computing was put into operation.

From this point the system gradually evolved in concept and in working equipment to its present form in which a central editing and computing station serves a number of remote research facilities. The operation of data collecting and input editing is described in considerable detail by Ryskamp. It is sufficient at this time to give a brief description of the system.

**Questions and Discussion** (p. 150)

**Logical Machine Design: A Selected Bibliography**—Douglas B. Netherwood (p. 155)

This paper presents a selection of current bibliographic references in the field of the logical design of machines. Selections were made with the objective of being useful and stimulatory to the wide variety of scientific persons who have some interest in this subject. An essential feature of the report is the extensive index of significant title words. Each indexed word is given in the complete context of the title in which it occurs.

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**SENEWS, Science Education Subcommittee Newsletter** (p. 185)

**PGEC News** (p. 188)

## Instrumentation

### Vol. I-7, No. 2, June, 1958

**Abstracts of Papers** (p. 102)

***Papers from Atlanta Instrumentation Conference***

**A Multichannel Digital Data Logging System**—Joseph Luongo (p. 103)

This paper describes a multichannel Digital Data Logging System which is capable of converting many forms of analog input information into digital form and recording the digital information on automatic recording devices. Each analog input channel is continuously converted into binary coded decimal digital form by a Federal Andicon analog-to-digital converter positioned by a servosystem. A Data Programmer controls the readout and recording sequence at a rate at which the printing or recording device operates. One information input channel at a time is scanned at a rapid rate and stored in an intermediate data storage section. The stored information is then read out at the slow rate required by the recording device, converted to the proper code to operate the recording device, and fed to the recorder. When the information input channel has been recorded, the Data Programmer selects the next channel and repeats the recording cycle. The System can be programmed to operate from any number of analog input channels.

**Economical On-Line Data Reduction System for Wind-Tunnel Force and Pressure Tests**—M. Bain and M. Seamons (p. 107)

The high speed data accumulation system developed for the Jet Propulsion Laboratory wind tunnels is being expanded into a complete on-line data-reduction facility capable of handling both force tests and pressure tests of two supersonic wind tunnels and eventually a hypersonic tunnel. Economy is attained through the use of perforated tape storage and high speed serial digital data-processing circuitry.

This paper reports on the equipment developed to implement an on-line system. Included are: high speed electronic data scanners; tape perforating equipment; additional input and output devices for a digital computer preparing final-data tapes suitable for both listing and plotting; tape controlled plotters for final coefficients; and fast word-at-a-time page printers.

Also included is a description of a recently installed multipressure measuring system capable of scanning 192 pressure sources in 40 seconds. This equipment utilizes but one pressure gauge which is switched to the various pressure lines. A report on the operating experience is included.

The paper concludes with a discussion of the saving in testing time, data-reduction time, and operating costs to be effected by the new system.

**Digital-Analog Function Generator**—R. W. Hofheimer and K. E. Perry (p. 111)

Digital-analog function generators are similar in application to digital-to-analog converters except that their outputs, instead of being proportional to the inputs, are proportional to functions of the inputs. If, for example, the input to a digital-analog function generator is $x$ in digital form, then the output can be an analog voltage proportional to sin $x$ or log $x$ or any of a wide variety of functions of $x$. Functions of more than one input variable can also be handled.

**A Multidecade Logarithmic Sweep**—R. W. Archbald, J. P. McNeill, and E. Schutzman (p. 118)

A logarithmic sweep is useful in the analysis of pulse-time modulation signals and in computing operations. The sweep can be used to measure the per cent modulation of pulse modulated waveforms where the per cent modulation is small.

A simple and unique procedure for designing a logarithmic sweep is described utilizing the output exponential function of a combination of resistive capacitive elements. The circuit is capable of covering a large number of decades of the input time variable. An accuracy of two per cent of the maximum output is obtained.

The basic circuit configuration consists of parallel RC combinations. The output is the sum of the exponential response of each parallel branch. The addition of the exponential functions is accomplished by means of a stabilized three-stage grounded emitter transistor feedback amplifier. Important design considerations are given for the amplifier. Equations are derived for ranges of two, three, and four decades in time. A typical circuit design is performed for a unit covering a range of three decades. Experimental results are given for this configuration.

**Topological Transformations by Electronic Scanning Techniques**—D. G. Aid, G. H. Balding, and C. Süsskind (p. 121)

A method of producing two dimensional topological transformations electronically is described, together with the circuits required, and some examples. The transformation is achieved in the driving circuits of a standard flying-spot camera tube equipped with a dual deflection system (*i.e.*, two sets of orthogonal deflection yokes or plates). Possible applications include scale expansions, conversions from linear to nonlinear scales, and correction of distortion.

**Correction** (p. 125)

## Microwave Theory and Techniques

### Vol. MTT-6, No. 3, July, 1958

**Message from the Editor** (p. 248)

**Frontispiece**—Lan Jen Chu (p. 249)

**Education for Electrical Engineering**—Lan Jen Chu (p. 250)

**Report of Advances in Microwave Theory and Techniques—1957**—Robert E. Beam (p. 251)

**A New Form of High-Power Microwave Duplexer**—P. D. Lomer and R. M. O'Brien (p. 264)

A new form of microwave duplexer, capable of handling twice as much power as an equivalent balanced duplexer, is described. It consists of a microwave bridge circuit and a power-sensitive half-wavelength phase shifter. A simple gas-discharge tube is used in the phase shifter, which changes the length in one arm of the bridge circuit by a half-wavelength for high-power and low-power microwave pulses, respectively.

The performance of one form of phase-shift duplexer has been measured over a frequency range from 8500 mc to 10,000 mc. The VSWR is less than 1:2 and the receiver isolation is greater than 30 db over most of the waveband. This is comparable to the performance of a balanced duplexer using the same components. The power handling capacity of the phase-shift duplexer is intrinsically twice as great as that of the balanced duplexer. For example, at a wavelength of 3 cm the phase-shift duplexer will operate unpressurized at a peak power level of 200 kw with a 2:1 safety factor on breakdown, whereas performance of a balanced duplexer at this power level is marginal.

**Radiation from a Rectangular Waveguide Filled with Ferrite**—G. Tyras and G. Held (p. 268)

This paper presents an approximate analytical solution to the problem of radiation from a ferrite-filled rectangular waveguide. The field distribution at the mouth of the guide is assumed to be unaffected by the termination of the guide. The vector Huygens' principle is applied to find the far-zone radiation field from the determined aperture field.

The solution to the problem is found in this manner for the cases of longitudinal and transverse magnetization of the ferrite. The transverse magnetization case is supplemented with a discussion of a specific numerical example which includes plots of the aperture field distribution and the phase angle as well as plots of the far-zone radiation field. The experimentally known phenomenon of the effect of the applied magnetic field upon the shift of the main lobe is demonstrated and verified analytically.

**Launching Efficiency of Wires and Slots for a Dielectric Rod Waveguide**—R. H. DuHamel and J. W. Duncan (p. 277)

This paper describes an experimental investigation of surface wave launching efficiency. Wires, rings, and slots are considered as exciters of the $\text{HE}_{11}$ mode on a dielectric rod image line. A formula is derived which relates the efficiency of a launcher to its impedance as a scatterer on the surface waveguide. Efficiency is obtained by using this formula and also by applying Deschamps' method for determining the scattering matrix coefficients of a two-port junction. Graphs are presented which illustrate the variation of efficiency with the dimensions of the launchers and with the parameter $\lambda_g/\lambda$, the ratio of the guide wavelength to the free space wavelength.

**Microwave Switching by Crystal Diodes**—Murray R. Millet (p. 284)

This paper gives the results of an investigation of the use of a microwave crystal as an RF switching element. Variation of a dc bias applied to the crystal will change its impedance, thereby providing an electronic control of microwave power. Empirical data are correlated with the physical structure of the crystal and its equivalent circuit to establish the frequency and power limitations of the switch. A comparison is also made of the switching properties of germanium and silicon crystals. Curves are given for predicting the switching capacity of any diode once its impedance has been normalized with respect to the characteristic impedance of the waveguide. Some methods are suggested for improving the bandwidth and power capacity of the crystal switch.

**Dielectric Image Lines**—S. P. Schlesinger and D. D. King (p. 291)

Some further studies on the dielectric image line are presented. Following a verification of field purity for the conventional image system, the effects of dielectric constant and dielectric geometry on loss, dispersion, and field extent are examined. Results are also discussed for an asymmetric line, *i.e.*, the case of dielectric binding medium partially submerged in an image surface.

**A Fast Ferrite Switch for Use at 70 KMC**—E. H. Turner (p. 300)

A normally open (attenuating) switch using ferrites has been built to operate in the 70-kmc region. It can be operated in 0.5 $\mu$sec and can be used with high duty cycles. The attenuation is about one db in the closed position and about 60 db in the open position. Construction and performance of the switch are discussed.

**Theoretical Analysis of the Operation of the Field-Displacement Ferrite Isolator**—Kenneth J. Button (p. 303)

A theoretical analysis of the resistance-sheet isolator is carried out, and numerical solutions are obtained for the forward and reverse propagation constants of the distorted dominant mode in a rectangular waveguide containing a transversely magnetized thick ferrite slab displaced slightly from the side wall. The microwave electric field patterns within the waveguide are plotted for several values of the physical design parameters of the isolator for which experimental performance data have been reported. Field patterns are used to describe the principles of the isolator and to select the optimum values of slab thickness, internal dc magnetic field, ferrite magnetization, and location of the slab in the waveguide for the idealized isolator. Evidence is presented to show that it is necessary to use a comparatively thick ferrite slab located in a very small usable range of distances from the side wall. The appropriate value of internal dc magnetic field is simply related to the magnetization of the ferrite and to the frequency. It has not been necessary to take into account the perturbing effects of the resistance card or matching techniques in order to explain the basic design principles.

**Reciprocity Relationships for Gyrotropic Media**—R. F. Harrington and A. T. Villeneuve (p. 308)

Reversal of the dc magnetic field in gyrotropic media transposes the tensor permeability and permittivity. It is shown that this also transposes the impedance, admittance, and scattering matrices of any device. It follows from this that the usual reciprocity statements for isotropic media apply to gyrotropic media if one reverses the dc magnetic field whenever an interchange of source and measurer is made.

**Broad-Band Stepped Transformers from Rectangular to Double-Ridged Waveguide**—E. S. Hensperger (p. 311)

The design of a series of broad-band Tchebycheff-type stepped waveguide transformers from various sizes of standard rectangular waveguides to a double ridged waveguide covering the frequency range of 4750 to 11,000 mc is described. Four separate transformers employing RG-67/U (WR-90), RG-68/U (WR-112), RG-106/U (WR-137), and WR-159 to Airtron ARA-133 double-ridged waveguide have been designed using this technique and cast in aluminum. The complete frequency range is covered by several pairs depending on which sizes of mating rectangular waveguides are desired. The RG-106/U design covers a frequency range of 53 per cent with a maximum VSWR of 1.08, while the other three designs each cover a slightly smaller frequency band with a VSWR not exceeding 1.05. Along with the experimental results obtained, an outline of the design method is given which can be used to design similar transformers between any compatible rectangular and double ridged waveguides.

**A Wide-Band Balun**—J. W. McLaughlin, D. A. Dunn, and R. W. Grow (p. 314)

Experimental results are given for a transformer from an unbalanced 50-ohm coaxial line to a balanced pair of 50-ohm coaxial lines. The design is one proposed by Marchand. The balance, standing wave ratio, and insertion loss are nearly constant over a 13 to 1 frequency range from 650 mc to 8500 mc. The standing wave ratio is less than 2.1 to one; insertion loss is about 0.5 db over this band of frequencies.

**Power-Flow Relations in Lossless Nonlinear Media**—H. A. Haus (p. 317)

The Manley-Rowe relations, originally derived for nonlinear lumped circuit elements, are generalized to include the power flow in the fields produced in the presence of lossless, nonlinear media. The generalization is carried out first for nonlinear anisotropic media with single-valued relations between the instantaneous $\bar{E}$ and $\bar{P}$, and $\bar{H}$ and $\bar{M}$. The proof is extended to include gyromagnetic media under small-signal excitation at the signal frequency (but large excitation at the pump frequency). The relations are applied to show under what conditions power gain can be achieved with a three-frequency and a four-frequency excitation of a ferrite. The form of the coupling coefficients in the electromagnetic operation of a ferrite amplifier is shown to be a consequence of the generalized Manley-Rowe relations.

**One Aspect of Minimum Noise Figure Microwave Mixer Design**—Saul M. Bergmann (p. 324)

A theory is derived which enables a direct measurement of the optimum RF impedance for minimum noise figure. This is achieved by an extension of Pound's method for loss measurements. Also, an analysis is made of the relation between minimum noise figure and maximum gain of the mixer represented as a two-port network.

The procedure consists of first matching the RF signal input terminals with short-circuited IF terminals. Next open-circuited IF terminal conditions are obtained by a circuit used by Pound. Then a reference plane is determined coinciding by preference with the plane of a maximum in the standing wave pattern of VSWR$=r$. A discontinuity is finally introduced that would have a VSWR of $\rho=\sqrt{r}$ and have its maximum or minimum at the plane of reference.

**A Broad-Band High-Power Vacuum Window for X Band**—H. J. Shaw and L. M. Winslow (p. 326)

Recent developments in high-power tubes for the 3-cm wavelength region have created a need for waveguide output windows which are capable of transmitting peak power in excess of 1 megw and average power in the neighborhood of 1 kw, and which have frequency bandwidths of about 15 per cent. This paper describes a structure which is designed to meet these electrical requirements, and which also has desirable physical and fabricational properties. A dielectric plug, which forms the vacuum seal, is used as one element of a three-element filter. The design procedure and experimental results are discussed.

**Correspondence** (p. 331)

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## Nuclear Science

### Vol. NS-5, No. 2, August, 1958

**Radiation Monitoring Over Long-Distance Telephone Lines and Direct Field Lines**—L. Costrell (p. 21)

Long-distance monitoring of radiation levels can be accomplished economically and reliably over commercial telephone line circuits. The system described was developed for the Atomic Energy Commission for the remote monitoring of gamma radiation resulting from atomic explosions. Though its principal use has been over long-distance telephone lines, it can also be used over direct field lines for monitoring sites within approximately 15 miles of the control station. The monitoring stations consume power only during challenges which last for about two minutes each. Total battery drain is therefore quite low, permitting the stations to remain unattended for long periods.

**A Dynamic Condenser Electrometer System for Beta Particle Detection**—S. Fox and R. B. Frank (p. 27)

An electrometer is described which has been commercially engineered to provide chemists, biologists, and medical technicians with a device for low-level $\beta$ counting using an ionization chamber. The operation of the instrument and typical applications are outlined. These include C-14 in gas samples, tritium in gas, and the same isotopes in liquid or solid form.

**Electron Multiplier Neutron Detectors**—L. Daum (p. 30)

A standard photomultiplier tube having uranium coated on the cathode is proposed for use in power reactor control. It will cover the neutron flux range from $10^6$ to $10^{11}$ neutrons/sec/cm$^2$ or the range from $10^3$ to $10^8$ neutrons/sec/cm$^2$. The electron multiplier neutron detector will compete with gamma compensated ionization chambers. Electronic discrimination of both gamma induced pulses and the natural alpha activity of the uranium is used to reduce the gamma sensitivity of the system.

**Transistorization of Nuclear Counting Circuits**—R. T. Graveson and H. Sadowski (p. 33)

The advantages of long operational life, low-power drain and miniaturization may be realized in nuclear counting circuits through the use of transistors. The disadvantage of instability, due to the effects of temperature change in the transistor, may be minimized in counting circuit designs. The predominant effects are a change in the grounded emitter current gain (beta) and a variation of the leakage current through the transistor ($I_{co}$). The binary circuit is analyzed for stability criteria, and may be tested conveniently through a simulation of $I_{co}$ for the maximum operating temperature. Representative circuits of a binary stage, amplitude discriminator, one-shot multivibrator, and ratemeters are included. These were designed using the criteria of a minimum Beta and a maximum $I_{co}$.

**Transistorized Radiation Monitors**—F. S. Goulding (p. 38)

The advantages of transistors over vacuum tubes in radiation instruments have long been realized but a somewhat different approach to circuit design must be followed in developing transistor instruments, as compared with that used in vacuum tube circuits, and this seems to have discouraged many from developing such circuits. The purpose of this paper is to describe in some detail the design principles included in some instruments developed at Chalk River in the past two years. Transistor high-voltage supplies, ratemeters, and pulse amplifiers are discussed and two instruments using these elements are described.

**Application of Transistors to Safety Circuits**—E. J. Wade and D. S. Davidson (p. 44)

The application of transistors to circuits controlling the rod release for shutdown of a nuclear reactor is described. No vacuum tubes are used in the circuit. The circuits were designed with maximum attention to reliability and fail-safe operation.

**Effects of Radiation on Vidicon Performance**—R. A. Davidson and B. H. Rosen (p. 46)

A commercial one-inch vidicon was exposed to a total radiation dosage of approximately $10^{15}$ NVT in the Brookhaven National Laboratories Nuclear Pile Reactor. Quantitative tests were devised for measuring tube aperture response, signal, noise, and photoconductor "dark" current.

No measurable degradation of performance occurred, except for decrease in signal output, which was attributed to radiation browning of the vidicon glass faceplate.

**Capacitance Level Gauge for Pressurizers of Pressurized Water Reactor Plants**—William Gernert (p. 50)

The pressure of a pressurized water nuclear power plant is maintained by heating water to saturation temperature in a vessel partially filled with water. The water level in this vessel, the pressurizer, must be monitored for safe plant operation. This paper describes the application of a well-known principle of liquid level measurement to this problem. The unusual operating conditions made the development of the device difficult.

**Fast Time Scale Simulation of a Reactor Control System**—G. Friedensohn and D. H. Sheingold (p. 53)

The setup and results of a reactor kinetics and servosystem simulation is presented. The reactor, a 50-megawatt high flux materials and engineering test reactor designated Belgian Reactor-2, is controlled by means of a saturating servomechanism actuating a cadmium containing regulating rod. The simulation was set up on a 100/1 time scale using GAP/R high-speed analog computing equipment, and solutions were presented repetitively.

Represented in the setup were six delayed neutron groups, variations in regulating rod effectiveness with displacement and reactor cycle time, four quadrant servomotor torque-speed characteristics, control rod position limiting, and a temperature coefficient of reactivity.

The results presented include the response of the system to: reactivity disturbances, changes in desired power set point, increase of power on a constant period, and transition from manual to automatic control during startup.

**NRU Reactor Neutron Level Control System**—C. G. Lennox and A. Pearson (p. 64)

A control system has been developed for the NRU reactor which performs automatic startup as well as steady power control. This paper describes the system characteristics and the circuits which determine them during startup and under steady power control.

**Thermal Power Control of the NRU Reactor**—C. G. Lennox and A. Pearson (p. 68)

When reactor power is controlled only by neutron leakage flux, a difficulty arises because the factor relating neutron flux level with reactor power is a function of the flux distribution in the reactor. Due to variation in control rod positions, the flux distribution will vary. This paper presents a method for handling the problem by measuring the reactor thermal power and using this to adjust the power level demand circuits. A stability analysis is also given.

**Correspondence** (p. 73)

**News and Views** (p. 74)

## Reliability and Quality Control

## PGRQC-13, July, 1958

**Mathematical Models for Determination of Efficient Troubleshooting Routes**—A. J. Hoehn and E. Saltz (p. 1)

**Computer Methods for Estimating Weibull Parameters in Reliability Studies**—J. H. K. Kao (p. 15)

In an earlier paper which appeared in these TRANSACTIONS, the author showed in the appendixes two methods of estimating the shape and scale parameters of a Weibull distribution from a set of life testing data. They are: 1) the method of least squares for the transformed data, and 2) the method of maximum likelihood for ungrouped data. It was pointed out that since the method of least squares was the simpler of the two, it could be used as a first approximation for getting the maximum likelihood estimate which involves solving, by trial and error, two simultaneous transcendental equations. As a measure of simplifying the computation of the analysis, the author suggested fixing the shape parameters at $m=1.7$, when studying the reliability of electron tubes. This value of $m=1.7$ was an average value based upon the life experience data, then available to the author, of some 2000 electron tubes.

With the wide popularity and availability of electronic computers, the above simplifications are no longer necessary, though still desirable for reasons explained in the text. This paper describes two additional methods for which the computers are almost indispensable. They are: 3) the method of maximum likelihood for grouped data, and 4) the method of minimized chi-squares. For the sake of discussion, the two previous methods (1 and 2) are briefly reviewed. As an illustration, the life testing data for five lots of some 400 electron tubes by a large tube manufacturer are treated by all four methods of estimation. Comparisons are made on the results and merits of these methods.

**Effects of Ambient Temperature on Electron Tubes**—K. Hopkinson (p. 23)

**Tomorrow's Quality Demands**—H. O. Imus (p. 29)

**Progress in TV-Receiver Reliability**—E. H. Boden (p. 36)

**Reliability Control Based on Multiple Sequential Feedback**—C. M. Ryerson (p. 45)

The classical approach to reliability improvement is based on a single feedback loop embracing design, development, production, and field service. A procedure of multiple sequential feedback is described which ties in with reliability prediction to provide a specified reliability on the first production run. Techniques are described which can be applied to many industrial operations. Illustrations show how tests and analyses of various kinds fit in.

**Student Announcement** (p. 57)

## Vehicular Communications

## PGVC-11, July, 1958

**Transistorized Microphones for Vehicular Communications**—H. A. Johnson and L. Rosenman (p. 3)

With the emphasis on intelligibility and reliability, the use of carbon microphones in vehicular communications is rapidly diminishing. Instead, magnetic and dynamic microphones with built-in transistor preamplifiers have been gaining considerable favor. For existing equipment, the amplifier draws its power from the carbon microphone circuit so that, in most cases, equipment changes are not required. Among the interesting possibilities in new equipment is a talk-back provision, whereby the microphone also acts as a speaker. Circuit considerations, environmental stability, and performance will be treated.

**New Type High Gain Station Antenna**—M. W. Scheldorf (p. 10)

There is an ever increasing demand for higher gain in omnidirectional fixed station antennas. A major factor in the pyramiding cost of these structures is the complexity of the feed system. Single feed point systems used in the past have had the disadvantage of low coupling between the driven element and the remotely located elements, resulting in highly tapered illumination and consequently lowered gain.

A new principle for a radiating array has been developed which uses only one feed point but with improved aperture illumination. New elements called "suppressors" isolate the effective portions of the radiating conductor without a need for direct excitation. Results with a unit having 10-db gain at 460 mc are described.

**The End of the Line**—T. J. McMullin (p. 20)

Discussion covers base station antennas in the 25–50-mc and 148–174-mc bands. Various types and combinations of antennas are discussed which produce shaped horizontal coverage patterns for noncircular areas so as to concentrate the radiation over the desired area. This approach to coverage is both economical from an investment standpoint and tends to reduce interference to other users.

Directional antennas with deep nulls on the back or side are effective in reducing cochannel, skip, desensitization, intermodulation, and transmitter noise types of interference.

Better utilization of the sides of towers can be obtained by the use of side-mount antennas to obtain either circular or eccentric horizontal patterns. This permits greater antenna gain than otherwise possible and also allows a number of systems with sufficient frequency separation to occupy the same tower structure.

**Sources of Interference Inherent in Vehicular Electrical Systems**—B. H. Short (p. 33)

**A New Arm for Vehicular Communications**—J. R. Neubauer (p. 34)

A comparative system study has been made to determine the performance requirements of a pocket carried receiver, which is compatible to existing land-mobile vehicular communication systems and can be used to extend their range of operational flexibility. The study employs a medium frequency analysis as a model. Using this method, a similar process yields the minimum performance specifications for frequencies of 43 and 150 mc. It is determined that such a device can be practically utilized within the desired range of coverage. A typical receiver now in production is described and a discussion of present and future applications illustrated.

**A Compact Low-Cost 150 MC Mobile Unit of Unusual Design**—M. A. Robbins (p. 42)

A VHF Mobile Unit is described which is one third the weight and employs 35 per cent less tubes than conventional units. The equipment meets current Canadian and U. S. Specifications, is rated at 10 watts RF output and has a sensitivity under 0.5 mv.

Compactness has been gained by the use of printed components, front-mounting, and considerable simplification of the detection and modulation circuits.

The frequency multiplication factor of the transmitter is 4, which considerably reduces the number of spurious emissions.

**Application of Single Sideband for Mobile Communication**—W. L. Firestone and H. Magnuski (p. 48)

**Transistorized Frequency Reference and Control System for 920 Channel Military Vehicular VHF-FM Receiver-Transmitter**—F. Bauer and D. Kammer (p. 55)

Receiver and transmitter frequency control is accomplished by two phase comparison loops. The primary loop compares the phase of the receiver VFO with the output of a Crystal Reference System containing a total of 13 crystals and using three stages of interpolation to cover the required frequency range. The secondary loop, on transmit, uses the controlled receiver VFO for the sidestep function and a crystal stabilized reference oscillator, which is capable of being modulated, for phase comparison. The receiver-transmitter covers a range of 30–76 mc in two bands with 50-kc channel spacing. The control system is capable of handling ±400 kc VFO setting plus drift error from nominal frequency. It employs transistors throughout and is capable of operation over a temperature range of $-55$ to $+85$°C. Thermistors and block filters are used to achieve gain and bandwidth stability. Receiver spurious frequencies due to the control system are down 85 db or more. Transmitter spurious radiation due to the control system is down 85 db or more except for a few channels near the receiver IF harmonic crossover frequencies, where the spurious radiation is down 75 db or more. High-speed crystal switching has been achieved in the reference system allowing rapid, automatic change of channels. The receiver frequency control system occupies approximately 40 cubic inches and employs individually packaged printed circuit plug-in subassemblies. Total receiver and transmitter control system power drain is less than one watt.

**The Meat of the Backbone**—A. C. Giesselman (p. 64)

Several particular system design problems are discussed, in connection with the design of "backbone" type vehicular communications systems. No attempt is made to cover the over-all problems of communications system design. This paper deals with some of the problems that are peculiar to "backbone" systems.

In particular, this paper discusses the variables affecting the size and seriousness of phasing areas between adjacent base stations, and methods of dealing with the problem. A method of automatic receiver selection, or "voting," is described, and over-all control methods are discussed.

**Dial Operated Mobile Radiotelephone Systems**—G. E. Dodrill (p. 71)

This paper describes radiotelephone equipment that makes it possible for small telephone companies with dial exchanges to offer 24-hour mobile radiotelephone service to their subscribers. Similar radiotelephone service can be given to subscribers in remote locations who could not otherwise be served by conventional wire line facilities. The equipment may also be used by a telephone company for its own use incident to construction and maintenance of outside plant. The equipment was developed to Rural Electrification Administration specifications by the Automatic Electric Company and Motorola, Inc., under separate contracts and has been successfully field-tested.

The telephone exchanges of most REA borrowers are of the automatic dial type and very few borrowers have toll centers with operators available to handle mobile calls. Lacking switchboard operators, these small companies can offer mobile radiotelephone service to their subscribers only on a limited dispatch or an automatic dial-operated basis.

**"Dial Direct" Automatic Radiotelephone System**—R. McDonald (p. 80)

The Dial Direct system enables radio units to dial any other mobile unit or any subscriber's land phone directly. Conversely, any land telephone subscriber may dial any mobile unit directly. The system is completely automatic and no operators are required. Through interconnections with other telephone companies, it is possible to make long distance toll calls from mobile units, simply by dialing a long distance operator, which is standard land telephone practice; however, if used with a telephone exchange using an automatic ticketing device and inter-city direct toll dialing, the long distance operator would not be required. It is also possible to use the system on private radiotelephone systems such as MCC operations or any other mobile users with duplex channel assignments by the addition of a private telephone exchange connected to the terminal of the Dial Direct base equipment.

**Vehicular Transmissions**—J. J. Egli (p. 86)

Available quantitative field strength data over irregular terrain is reviewed and interpreted for its usefulness in vehicular systems engineering. Included are terrain effects vs. frequency, antenna heights and distance, field strength fluctuation, and man-made noise and its effects on vehicular reception at various frequencies. The usefulness of these data and their relationship to vehicular field usage is discussed.

**Address by Warren E. Baker** (p. 91)

**Panel Discussion—Vechicular Communications and the Radio Spectrum** (p. 96)

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# Abstracts and References

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**NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.**

**The Index to the Abstracts and References published in the PROC. IRE from February, 1957 through January, 1958 is published by the PROC. IRE, May, 1958, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, and included in the March, 1957 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.**

All abstracts in the September, 1958, issue of PROCEEDINGS OF THE IRE should have their serial numbers increased by one. The missing number, 2275, is as follows:

**621.387.002.2:621.318.57** **2275**

**A Low-Cost Cold-Cathode Trigger Tube**—A. Turner. (*Electronic Eng.*, vol. 30, pp. 166–169; April, 1958.) A design for economic production is described.

**Acoustics and Audio Frequencies** ...... 1780
**Antennas and Transmission Lines** ..... 1780
**Automatic Computers** ................ 1781
**Circuits and Circuit Elements** ......... 1781
**General Physics** .................... 1783
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**Propagation of Waves** ............... 1790
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**Subsidiary Apparatus** ............... 1791
**Television and Phototelegraphy** ....... 1792
**Transmission** ...................... 1792
**Tubes and Thermionics** .............. 1792
**Miscellaneous** ..................... 1794

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

## U.D.C. NUMBERS

Extensions and changes in U.D.C. numbers published in P.E. Notes, up to and including P.E. Note 609, will be introduced in Abstracts and References where applicable, notably the subdivisions of 621.372.8 waveguides published in P.E. Note 594. U.D.C. publications are obtainable from The International Federation for Documentation, Willem Witsenplein 6, The Hague, Netherlands, or from The British Standards Institution, 2 Park Street, London, W.1, England.

## ACOUSTICS AND AUDIO FREQUENCIES

**534.2-8-14** **2610**

**Investigation of an Ultrasonic Field in a Liquid**—B. Labory and G. Laville. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1401–1403; October 21, 1957.) Measurements have been made to determine the force exerted on an Al cylinder in the sound field of a quartz transducer operating at frequencies up to 7 mc in water. Results are compared with theoretical calculations of the radiation field.

**534.2-8-14:534.6** **2611**

**Apparatus for Measuring the Attenuation of Ultrasonic Propagation in Liquids**—G. Laville. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1523–1526; October 28, 1957.) Description of apparatus designed in accordance with the results of earlier measurements (2610 above), and a report on its application in determining the ultrasonic absorption of sugar solutions.

**534.2-8-14:534.6** **2612**

**Two-Crystal Interferometric Method for Measuring Ultrasonic Absorption Coefficients in Liquids**—R. S. Musa. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 215–219; March, 1958.) Two matched quartz crystals are used. A standard signal generator drives one of the crystals continuously. The amplitude of the resulting pressure waves is measured at the other crystal by means of a communications receiver and a voltmeter.

**534.22-14:546.212** **2613**

**On the Temperature Variation of the Velocity of Sound in Water**—C. Sălceanu. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1371–1374; October 21, 1957.) Results of measurements at a frequency of 1315 cps at 27°–81°C show that the velocity has a maximum value at about 62°C. See also 1296 of 1958 (Greenspan and Tschiegg).

**534.78** **2614**

**Dynamic Analogue Speech Synthesizer**—G. Rosen. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 201–209; March, 1958.) "A dynamically controllable electrical analog of the vocal tract capable of synthesizing sequences of speech sounds is described. The acoustic transmission line between the glottis and lips in the human vocal tract is realized electrically by eleven electronically controlled variable *LC* section plus three fixed sections."

**534.78:621.391** **2615**

**Message Procedures for Unfavourable Communications Conditions**—I. Pollack. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 196–201; March, 1958.) "Several message procedures, designed to improve speech communications under extremely unfavorable speech-to-noise ratios, were examined. A message procedure based upon the informational principle of successive selections among a reduced number of alternatives was strikingly superior to a message procedure based upon the repetition of a single selection among a larger number of alternatives."

**534.79** **2616**

**Loudness of Periodically Interrupted White Noise**—I. Pollack. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 181–185; March, 1958.)

**534.846** **2617**

**Studio for Listening Tests**—L.O. Dolanský. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 175–181; March, 1958.) The design, construction, acoustical testing, and articulation testing of a studio giving reasonably constant listening conditions are described. The reverberation time was found to be about 0.5 second.

**621.395.61** **2618**

**Noise Shield for Microphones used in Noisy Locations**—M. E. Hawley. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 188–190; March, 1958.) The rubber noise shield developed significantly improves the speech/noise ratio of microphones for military use.

## ANTENNAS AND TRANSMISSION LINES

**621.372.2** **2619**

**Electromagnetic Wave Propagation in an Almost Periodic Waveguide**—A. A. Sharshanov and K. N. Stepanov. (*Zh. Tech. Fiz.*, vol. 27, pp. 1474–1481; July, 1957.) A mathematical analysis is presented of a) wave propagation in cavity resonators, b) propagation at a frequency near to the transmission threshold, and c) the propagation of electromagnetic waves in a cylindrical waveguide loaded with dielectric disks. The solution of differential equations with slowly varying coefficients is considered.

**621.372.2** **2620**

**Transmission-Line Discontinuities**—K. W. H. Foulds. (*Electronic and Radio Engr.*, vol. 35, pp. 263–267; July, 1958.) The conditions necessary for a transmission line with two identical discontinuities to be matched in the steady state to the generator are examined. The way in which the steady-state conditions are derived from the transient behavior is explained.

**621.372.2** **2621**

**The Effects of Reflections from Randomly Spaced Discontinuities in Transmission Lines**—R. K. Moore. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 121–126; April, 1957. Abstract, PROC. IRE, vol. 45, p. 1036; July, 1957.

**621.372.2** **2622**

**The Probability of Specified Losses at Mismatched Junctions**—J. H. Craven. (*J. Brit. IRE*, vol. 18, pp. 293–296; May, 1958.) "Probability contours are presented for specified losses (<1 db to 6 db) at junctions between networks or lines for a range of voltage SWR from 1 to 10."

**621.372.2:[621.372.826+621.396.677.7** **2623**

**Single-Slab Arbitrary-Polarization Surface-Wave Structure**—R. C. Hansen. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 115–120; April, 1957. Abstract, PROC. IRE, vol. 45, p. 1036; July 1957.) See also 3733 of 1957 (Plummer and Hansen).

621.372.2:621.385.029.6 2624

**Fast Waves in a Coaxial Helical Line**—L. N. Loshakov and E. B. Ol'derogge. (*Radiotekhnika, Mosk.*, vol. 12, pp. 25–30; June, 1957.) Waves with a phase velocity exceeding that of waves in an infinite dielectric are investigated on the assumption that the inner conductor (helix) of the line can be replaced by an anisotropically conducting surface. Conditions are established under which the propagation of such waves is possible.

621.372.22 2625

**The Transmission Characteristics of a Line consisting of Axially Stacked Insulated Metal Rings**—G. Piefke. (*Arch. elekt. Übertragung*, vol. 11, pp. 423–428; October, 1957, pp. 449–454; November, 1957.) The mathematical treatment developed earlier (3035 of 1957) is applied to an investigation of the "ring-element waveguide." The axial thickness of the insulated rings is much less than the wavelength. The propagation constants for various modes are calculated.

621.372.821 2626

**Coupled Strip Transmission Lines with Rectangular Inner Conductors**—J. D. Horgan. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 92–99; April, 1957. Abstract, Proc. IRE, vol. 45, p. 1036; July, 1957.)

621.372.823:621.372.852.1 2627

**The Effects of Mode Filters on the Transmission Characteristics of Circular Electric Waves in a Circular Waveguide**—W. D. Warters. (*Bell Sys. Tech. J.*, vol. 37, pp. 657–677; May, 1958.) Measurements have been made showing the mode conversion effects for the $TE_{01}$ mode in a circular waveguide at a frequency of 9 kmc using a pulse technique. The conversion to other modes has been measured and mode filters have been developed which are effective against all the spurious modes generated. The effect of filter spacing on pulse distortion and attenuation is shown and the spacing of the filters is discussed.

621.372.825 2628

**Semicircular Ridges in Rectangular Waveguides**—J. Van Bladel and O. Van Rohr, Jr. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 103–106; April, 1957. Abstract, Proc. IRE, vol. 45, p. 1036; July, 1957.)

621.372.829:621.372.852.1 2629

**Research Models of Helix Waveguides**—C. F. P. Rose. (*Bell Sys. Tech. J.*, vol. 37, pp. 679–688; May, 1958.) The construction of a waveguide for the $TE_{01}$ circular mode is discussed. The waveguide has a helix on the inner wall which acts as a mode filter. The design and construction of such a waveguide for use at 55 kc is described.

621.372.829:621.385.029.6 2630

**Helical Waveguides—Closed, Open and Coaxial**—G. M. Clarke. (*J. Brit. IRE*, vol. 18, pp. 359–361; June, 1958.) "The application of helical waveguides to electron-beam amplifiers employing slow-wave structures is described. The performances of the various possible configurations are discussed." See 353 of 1958 (Waldron).

621.372.852.1 2631

**The Design of Inductive Post-Type Microwave Filters**—M. H. N. Potok. (*J. Brit. IRE*, vol. 18, pp. 263–272; May, 1958.) Using experimental and theoretical results it is shown that filters can be designed to have a desired voltage SWR within the pass band and a given insertion loss outside it. Optimum design of three and four-cavity filters is discussed.

621.372.855 2632

**Theoretical Analysis of the Design of a High-Power Waveguide Load**—V. Hlubuček. (*Slab Obz., Praha*, vol. 18, pp. 420–425; July, 1957.) Conditions for the uniform absorption of power along the load with minimum voltage SWR are derived. Practical design details are given.

621.396.67:538.221 2633

**Magnetic-Field Antenna**—W. J. Polydoroff. (*Electronic Ind.*, vol. 17, pp. 66–68; March, 1958.) The use of magnetic materials, such as ferrites, in the design of high-gain antennas is briefly discussed. The pick-up of such antennas is best considered in terms of the magnetic rather than the electric field.

621.396.676 2634

**Flush-Mounted Aircraft Aerials**—M. Lorant. (*Wireless World*, vol. 64, pp. 337–338; July, 1958.) The use of scale models in the study of the radiation patterns of the antennas is briefly outlined.

621.396.677.062.8 2635

**Aerial Selectors**—L. Leng. (*Brown Boveri Rev.*, vol. 44, pp. 446–450; October, 1957.) Indoor-type antenna switching installations for SW transmitters are described.

621.396.677.3 2636

**The Directional Aerial Installation of the "Deutsche Welle"**—K. Alt and H. König. (*Brown Boveri Rev.*, vol. 44, pp. 427–433; October, 1957.) Description of the SW directional antenna system erected at Jülich, Germany.

621.396.677.3:621.396.712 2637

**Long-Distance H.F. Broadcasting**—T. W. Bennington. (*Wireless World*, vol. 64, pp. 331–336; July, 1958.) The characteristics of the transmitting antenna array for good broadcast coverage of a distant area are discussed.

621.396.677.71 2638

**A Low-Frequency Annular-Slot Antenna**—J. R. Wait. (*J. Res. Natl. Bur. Stand.*, vol. 60, pp. 59–64; January, 1958.) The radiation characteristics of an annular slot cut in an ideally conducting ground plane are discussed. The voltage impressed between the concentric edges is assumed to be constant around the slot. The annular slot is backed by a hemispherical cavity which has imperfectly conducting walls. For a specified voltage, the power radiated in the upper half-space and the power absorbed by the hemispherical cavity are calculated. It is indicated that the power absorbed can be reduced greatly by lining the walls of the cavity with a wire mesh. A flush-mounted antenna of this type at low frequencies may have certain practical advantages over the more conventional monopole. See also 1326 of 1958.

621.396.677.81:538.566 2639

**The Impedance of a Wire Grid Parallel to a Dielectric Interface**—J. R. Wait. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 99–102; April, 1957. Abstract, Proc. IRE, vol. 45, p. 1036; July, 1957.) See also 3273 of 1957.

621.396.677.833.1 2640

**Far-Field Radiation of a Cheese Aerial**—R. F. Kyle. (*Electronic and Radio Engr.*, vol. 35, pp. 260–262; July, 1958.) The phase and amplitude distributions across the aperture of an *X*-band cheese antenna were measured and the radiation pattern was calculated. Good agreement was obtained with the measured patterns.

621.396.679 2641

**On the Calculations of Transverse Current Loss in Buried-Wire Ground Systems**—J. R. Wait. (*Appl. Sci. Res.*, vol. B7, no. 1, pp. 81–86; 1958.) An expression is derived for the impedance between a wire grid buried in a homogeneous ground and an overhead conducting plane. The power loss due to transverse currents in buried-wire systems for antennas is calculated.

## AUTOMATIC COMPUTERS

681.142 2642

**A Survey of Delay Lines for Digital Pattern Storage**—S. Morleigh. (*Electronic Eng.*, vol. 30, pp. 380–387; June, 1958.) A review of electromagnetic and ultrasonic delay lines for use over a wide range of delay times. Wire-type acoustic delay lines using magnetostrictive transducers, acoustic lines using liquids or solids as delay media, and both the continuous and lumped parameter types of electromagnetic delay line are examined.

681.142 2643

**Modern Trends in Analogue Computation**—B. B. Murphy. (*IVA, Stockholm*, vol. 28, pp. 336–350; 1957.) (In English.)

681.142 2644

**A Special Analogue Computer for Calculating the Oscillations of Diaphragms**—H. Dehnert. (*Elektronik*, vol. 6, pp. 301–303; October, 1957.)

## CIRCUITS AND CIRCUIT ELEMENTS

621.3.001.4:621.395.64 2645

**Passive Components for Submarine Telephone Cable Repeaters**—M. C. Wooley. (IRE Trans. on Reliability and Quality Control, no. PGRQC-12, pp. 14–24; November, 1957.) The design and inspection of inductors, resistors, and transformers are briefly described. Details of the inspection of silvered mica capacitors are given as an example of the procedure adopted.

621.3.042.4(083.57) 2646

**Nomogram for Air-Gap Design**—A. C. Sim. (*Electronic and Radio Engr.*, vol. 35, pp. 250–251; July, 1958.) A nomogram is given for determining the relation between the actual air gap in a choke or transformer and its effective value for normal types of laminations.

621.316.825 2647

**Thermistors**—K. R. Patrick. (*Electronic and Radio Engr.*, vol. 35, pp. 242–249; July, 1958.) A review is given of the various types of thermistor, their method of manufacture, and the physical theory of their operation. Some typical applications are outlined.

621.318.435:621.373.443 2648

**Saturable Reactors fire Radar Magnetrons**—H. E. Thomas. (*Electronics*, vol. 31, pp. 72–75; May 9, 1958.) "Magnetic modulator uses saturable reactors to convert input sine wave into narrow, high-peak-power output pulses. Basic action of current-pulse compression with magnetic modulators is explained. Polarizing and differentiating circuits, delay-line wave shaping, pulse permeability measurements, cancellation effects and related features leading to improved design are discussed."

621.318.57:621.387 2649

**A Multichannel Dekatron Scaling Unit**—F. W. Lovick. (*Electronic Eng.*, vol. 30, pp. 394–395; June, 1958.) Equipment is described for counting simultaneously in up to six channels. A variety of counting rates can be obtained.

621.319.4 2650

**The Duroplast Capacitor**—R. Bretschneider. (*Nachrtech. Z.*, vol. 7, pp. 460–465; October, 1957.) A tubular paper capacitor impregnated with epoxy resin which eliminates the need of a sealed metal can. Constructional and electrical data are given.

621.372:621.396.822:530.162 2651
**Thermal Fluctuations in a Nonlinear System**—N. G. van Kampen. (*Phys. Rev.*, vol. 110, pp. 319–323; April 15, 1958.) An electric circuit containing a voltage-dependent resistance $R(V)$ and a capacitance is studied. A general method is given for finding the spectral density of current fluctuations, and explicit results are obtained for two special forms of $R(V)$.

621.372.4 2652
**A Numerical Method for the Determination of a Two-Pole Function which Approximates a Given Complex Function in a Band of Real Frequencies**—R. Unbehauen. (*Arch. elekt. Übertragung*, vol. 11, pp. 440–448; November, 1957.)

621.372.413:621.318.134 2653
**On the Theory of Anisotropic Obstacles in Cavities**—W. Hauser. (*Quart. J. Mech. Appl. Math.*, vol. 11, pt. 1, pp. 112–118; February, 1958.) Variational expressions are derived for the resonance frequencies of a cavity containing a material with tensor electromagnetic properties.

621.372.413:621.372.54.029.6 2654
**Circularly Polarized Microwave Cavity Filters**—C. E. Nelson. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 136–147; April, 1958. Abstract, Proc. IRE, vol. 45, p. 1036; July, 1957.) See also 41 of 1957.

621.372.5 2655
**Synthesis of Driving-Point and Transfer Functions by Continued-Fraction Expansion**—R. E. Vowels. (*Aust. J. Appl. Sci.*, vol. 8, pp. 151–168; September, 1957.) "A method of synthesis of driving-point functions has been developed in which more than one network element may be included in each branch of the ladder network. The method is first applied to *RL* and *LC* two-element type networks and then extended to the general *RLC* network. Four-terminal networks having prescribed driving-point and transfer impedances are synthesized in a similar manner."

621.372.54 2656
**The Unbalanced Symmetrical Parallel-T Network taking account of Condenser Loss**—K. Posel. (*Trans S. Afr. Inst. Elect. Engrs.*, vol. 48, pt. 7, pp. 243–257; July 1957. Discussion, pp. 257–260.) The network is analyzed without adopting the usual approximations, and its application to wave-analyzer and oscillator circuits is discussed. See 3425 of 1957.

621.372.54.029.64 2657
**Synthesis of a Class of Microwave Filters**—H. Seidel. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 107–114; April, 1957. Abstract, Proc. IRE, vol. 45, p. 1036; July, 1957.)

621.372.543.3:621.375.126.029.3 2658
**Bifilar-T Trap**—A. Hendry and A. G. McIntosh. (*Electronic and Radio Engr.*, vol. 35, pp. 254–259; July, 1958.) Details are given of a circuit with a bifilar-T trap designed for rejecting the second harmonic of a 1-kc signal in an infrared detector amplifier. Other applications of the bifilar-T trap are considered, *e.g.*, a tuned AF amplifier with a bandwidth of a few hundred cycles having a narrow band of high attenuation at the center, and a narrow-band feedback amplifier.

621.373.2.029.65 2659
**Production of Millimetre Waves by a Spark Generator**—J. Hart. (*J. Appl. Phys.*, vol. 29, p. 743; April, 1958.) A brief account of experiments which suggest that the spark generator does not offer a practical means of extending the radio spectrum to wavelengths less than 5 minutes.

621.373.43 2660
**Circuits for Forming Pulses from a Sinusoidal Voltage using a Relatively Low Supply Voltage**—V. I. Zabavin. (*Radiotekhnika, Mosk.*, vol. 12, pp. 73–77; May, 1957.) Circuits are considered which have a number of advantages over multivibrator and trigger circuits. Tube, transistor, or hybrid circuits can be used.

621.373.431.1 2661
**The Schmitt Multivibrator**—G. L. Swaffield. (*Wireless World*, vol. 64, pp. 344–348; July, 1958.) A detailed design procedure is given and applications of the circuit are outlined.

621.373.431.1:621.314.7 2662
**A Method for Sharpening the Output Waveform of Junction-Transistor Multivibrator Circuits**—A. E. Jackets. (*Electronic Eng.*, vol. 30, pp. 371–374; June, 1958.) Extension of previous work (2340 of 1956). A method of designing the circuit to reduce the recharging time of the coupling capacitor is given. An improvement in waveform at the collector of one transistor is achieved with an accompanying deterioration of the other output.

621.373.44:621.317.34 2663
**Design of a Dual Pulse Code Train Generator**—A. M. Leuck and T. I. Humphreys. (*Electronic Equipment*, vol. 5, pp. 22–25; November, 1957.) Description of a pulse train generator, developed for delay-line testing, which provides a double train of pulses of variable separation.

621.373.52 2664
**Transistor Oscillators and their Load-Independent Properties**—W. Herzog. (*Nachrtech. Z.*, vol. 10, pp. 564–569; November, 1957.) The equivalence of the "internal" and the external feedback in a transistor oscillator circuit is established. Two types of load-independent oscillators are considered, one with a load impedance in parallel with the equivalent passive quadripole, and the other with the impedance in series. The conditions for obtaining an oscillator with two load-independent impedances, and a load-independent oscillator in the form of a six-terminal network are examined. See also 2699 of 1957 (Frisch and Herzog).

621.373.52 2665
**Experimental and Theoretical Investigation of a Frequency-Stabilized Transistor Oscillator for 8 Mc/s**—H. Schaffhauser and M. J. O. Strutt. (*Arch. elekt. Übertragung*, vol. 11, pp. 455–460; November, 1957.) The condition for oscillation of a feedback oscillator is derived. The amplifier, its load, and the feedback network are treated as a single cascaded quadripole. Output voltage and frequency variations as a function of temperature, load, and supply voltage were measured on a practical circuit containing a quartz crystal resonator. A general rule for adjusting the emitter series resistance so that the input parameters remain constant during variations of temperature could not be established.

621.373.52 2666
**Designing Transistor Circuits—Sinusoidal Transistor Oscillators: Part 1**—R. B. Hurley. (*Electronic Equipment*, vol. 5, pp. 22–25; September, 1957.) A criterion for the generation of a single sinusoidal waveform is developed from linear network theory, and applied to basic transistor oscillator circuits. Practical problems of distortion are discussed.

621.373.52.012.8 2667
**Designing Transistor Circuits—Small-Signal Parameters and Equivalent Circuits**—R. B. Hurley. (*Electronic Equipment*, vol. 5, pp. 28–33; November, 1957.) The merits of various equivalent circuits for transistors are discussed, with emphasis on the common-base-derived *y*, *h*, and T arrangements.

621.374.4+621.376.223]:621.314.632 2668
**Performance of Three-Millimetre Harmonic Generators and Crystal Detectors**—J. M. Richardson and R. B. Riley. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 131–135; April, 1957. Abstract, Proc. IRE, vol. 45, p. 1036; July, 1957.)

621.375 2669
**A Method for Investigating Amplifying Circuits with Characteristic Equations of the Third Degree for Short Build-Up Times**—E. N. Mokhov. (*Radiotekhnika, Mosk.*, vol. 12, pp. 54–61; May, 1957.) A method is proposed in which a number of difficulties in design are eliminated. As an example, results are given of an investigation of a correction circuit using an inductance in the grid circuit.

621.375.1.029.3:621.395.625.3:621.396.665 2670
**Squelch Circuit mutes Magnetic-Tape Echoes**—D. Cronin. (*Electronics*, vol. 31, pp. 66–67; May 9, 1958.) A biased-diode type of AVC is described which eliminates "echoes" due to print-through effect by rejecting outputs lower than 40 db below peak signal level.

621.375.2.018.75 2671
**The "Cathoguard"**—L. G. White. (*Wireless World*, vol. 64, pp. 312–313; July, 1958.) A method of reducing the input and output capacitances of a wide-band pulse amplifier is described.

621.375.226:621.372.54 2672
**The Asymmetry of Two-Circuit Tuned and Coupled Filters due to Feedback via the Grid-Anode Capacitance $C_{ga}$**—E. G. Woschni. (*Hochfrequenztech. u. Elektroakust.*, vol. 66, pp. 15–19; July, 1957.) The asymmetry due to feedback in the characteristics of an IF amplifier is calculated a) for a circuit with tuned filters and b) for coupled filters. The limiting conditions for instability are also determined. See also 2689 below.

621.375.4.126.029.3 2673
**Transistor $Q$-Multiplier for Audio Frequencies**—G. B. Miller. (*Electronics*, vol. 31, pp. 79–81; May 9, 1958.) The use of positive feedback to increase the selectivity of a tuned circuit is discussed. The performance of a practical circuit giving, for example, a $Q$ of 1000 at 200 cps is described.

621.375.4.13 2674
**Transistor A.C. Amplifier uses Multiple Feedback**—H. Lefkowitz. (*Electronics*, vol. 31, pp. 84–85; May 23, 1958.) The use of shunt and series negative-feedback loops simultaneously in each stage is considered.

621.375.9:537.312.62:621.317.32.024 2675
**A Sensitive Superconducting "Chopper" Amplifier**—A. R. De Vroomen and C. Van Baarle. (*Physica*, vol. 23, pp. 785–794; August, 1957.) An amplifier based on a magnetically modulated Tl wire and similar in principle to that due to Templeton (518 of 1956) is described. It is designed for the study of thermoelectricity at liquid-He temperatures.

621.375.9:538.569.4.029.64 2676

**21-Centimetre Solid-State Maser**—S. H. Autler and N. McAvoy. (*Phys. Rev.*, vol. 110, pp. 280–281; April 1, 1958.) A three-level solid-state maser using $K_3Co(CN)_6$ doped with $K_3Cr(CN)_6$ has been operated as an amplifier at 1382 mc. The design is somewhat different from that previously reported [2037 of July (Artman, *et al.*)] which operates in the same frequency range.

621.375.9:538.569.4.029.64 2677

**Two-Level Solid-State Maser**—P. F. Chester, P. E. Wagner, and J. G. Castle, Jr. (*Phys. Rev.*, vol. 110, pp. 281–282; April 1, 1958.) Microwave amplification and oscillation have been observed at 4.2°K using two-level electron-spin systems. The materials used were single crystals of quartz and of magnesium oxide, each containing paramagnetic defects.

621.375.9:538.569.4.029.6 2678

**Maser Oscillator with One Beam through Two Cavities**—W. H. Wells. (*J. Appl. Phys.*, vol. 29, pp. 714–717; April, 1958.) The behavior is investigated using a geometrical representation of the Schrödinger equation, and a qualitative explanation is given of the ability of the maser to oscillate simultaneously at two frequencies.

621.375.9:621.3.011.23:621.314.63 2679

**A Low-Noise Wide-Band Reactance Amplifier**—B. Salzberg and E. W. Sard. (PROC. IRE, vol. 46, p. 1303; June, 1958.)

621.375.9.029.6:621.3.011.3 2680

**Circuit Analogues of Suhl-Type Masers**—K. W. H. Stevens. (*J. Electronics Control*, vol. 4, pp. 275–279; March, 1958.) A tuned circuit in which inductance varies with time, and two coupled tuned circuits in which mutual inductance varies with time, are analyzed and shown to act as amplifiers under certain conditions. These considerations are preliminary steps to the final problem leading to the Suhl-type maser (3076 of 1957). See also 2681 below.

621.375.9:621.3.011.3 2681

**Amplification using a Processing Magnetic Moment**—K. W. H. Stevens. (*J. Electronics Control*, vol. 4, pp. 280–284; March, 1958.) "An account is given of the analysis of an arrangement in which two tuned circuits are coupled to a precessing magnetic moment. It is shown that with $\omega_1+\omega_2=\omega$, where $\omega_1$ and $\omega_2$ are the resonance frequencies of the circuits and $\omega$ the precession frequency, useful amplification can be obtained at $\omega_1$. In the course of the analysis the Bloch equations are solved to a higher order in approximation than is usual."

621.375.9:621.385.029.63:537.533 2682

**Parametric Amplification of the Fast Electron Wave**—Adler. (See 2934.)

621.375.9.029.63:621.3.011.23:621.314.63 2683

**Experimental Characteristics of a Microwave Parametric Amplifier using a Semiconductor Diode**—H. Heffner and K. Kotzebue. (PROC. IRE, vol. 46, p. 1301; June, 1958.) A rectangular cavity simultaneously resonant at 3.5, 2.3, and 1.2 kmc is used with a Ge junction diode having a zero-bias capacitance of 1 pF and a spreading resistance of 5Ω. With a pumping signal applied at 3.5 kmc, amplification can be obtained at either of the lower frequencies. At 16 db gain preliminary measurements show a noise figure less than 4.8 db.

621.375.9.029.64:621.3.011.23:621.314.63 2684

**Noise-Figure Measurements on Two Types of Variable-Reactance Amplifiers using Semiconductor Diodes**—G. F. Herrman, M. Uenohara, and A. Uhlir, Jr. (PROC. IRE, vol. 46, pp. 1301–1303; June, 1958.) The use of semiconductor diodes in an "up-converter" (460 mc to 9.4 mc) and in a negative-resistance amplifier at 6 kmc is described. A bandwidth of 8 mc was obtained with the latter at a maximum gain of 18 db, and a noise figure as low as 3 db has been achieved.

621.376 2685

**An Experimental Investigation of the Method for Obtaining an Optimum Amplitude Phase Modulation**—S. I. Tetel'baum and Yu. G. Grinevich. (*Radiotekhnika, Mosk.*, vol. 12, pp. 42–47; May, 1957.) A report on experiments confirming the main premises of the theory of the method proposed by Tetel'baum (*ibid.*, vol. 5; February, 1950). See 254 of 1956 (Vereschagim).

621.376:538.632:537.311.33 2686

**Balanced Modulators based on the Hall Effect in Semiconductors**—L. S. Berman, S. S. Raĭkhman, and Z. A. Khalfin. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1597–1598; July, 1957.) Balanced modulators based on the Hall effect in HgSe and *n*-type Ge are investigated. Sensitivities are too low for practical use.

621.376.232:621.317.61:621.372.8 2687

**A Phase-Sensitive Detector**—K. G. Beauchamp. (*Electronic Ind.*, vol. 17, pp. 74–77; March, 1958.) A detailed circuit is given of a system for measuring the voltage SWR in a waveguide by detecting a modulated carrier. By using a very narrow effective bandwidth detection is possible at signal levels as low as 0.01 $\mu$v.

621.376.232.2 2688

**Analysis of Transient Processes in Diode Detection by a Method based on the Use of Low-Frequency Equivalent Circuits**—L. S. Gutkin and O. S. Chentsova. (*Radiotekhnika, Mosk.*, vol. 12, pp. 31–44; June, 1957.) A method is proposed for analyzing the transient processes in a system consisting of a HF amplifier and a diode detector. The method is based on the linear approximation of the processes occurring during detection and on the replacement of the detector and of the amplifier circuits by equivalent LF circuits. Various types of circuit and various shapes of the envelopes of the input signal are considered.

621.376.3:621.372.54 2689

**The Distortion of Frequency-Modulated Oscillations due to Asymmetry in Two-Circuit Filter Networks**—E. G. Woschni. (*Hochfrequenztech. u. Elektroakust.*, vol. 66, pp. 11–15; July, 1957.) Second- and third-order distortion factors for quasi-static and dynamic distortion conditions are calculated using formulas derived from a series expansion of the filter phase and attenuation characteristics.

## GENERAL PHYSICS

535.325:535.14 2690

**Quantum Theory of the Refractive Index**—C. A. Mead. (*Phys. Rev.*, vol. 110, pp. 359–369; April 15, 1958.) A perturbation theory is used to obtain a unitary transformation which approximately diagonalizes the total Hamiltonian for a system made up of a radiation field in interaction with gas molecules.

537.37 2691

**A Model of Phosphors on the Basis of Quantum Mechanics: Part I—Kinetics of Electron and Phonon Reactions**—H. Stumpf. (*Z. Naturf.*, vol. 12a, pp. 153–167; February, 1957.) The optical behavior of a phosphor is discussed assuming that two types of defect center exist in the crystal.

537.226.1 2692

**A Property of Dielectric Constants of Dielectrics in Thermal Equilibrium**—M. Peter. (*J. Math. Phys.*, vol. 36, pp. 347–350; January, 1958.) Theoretical discussion of dielectrics with or without internal sources of energy. A lumped-circuit model of a molecular amplifier with Lorentz-shaped bandpass characteristic is derived.

537.311.33:539.2 2693

**Irreversible Thermodynamics and Carrier Density Fluctuations in Semiconductors**—K. M. van Vliet. (*Phys. Rev.*, vol. 110, pp. 50–61; April 1, 1958.) The formalism of irreversible thermodynamics is applied to the kinetics of carrier transitions in semiconductors. The thermodynamic forces, the generalized resistances, and admittance functions are introduced. It is shown that the thermodynamic forces which establish the regression of a perturbed state to equilibrium are the differences of the quasi-Fermi levels that have to be assigned to each group of carriers; the generalized resistances are simply related to the transition rates. The kinetic equations for the rate of change of the various carrier concentrations are then written in a unified form, the spectral density matrix of the spontaneous carrier fluctuations being found from the admittance matrix. The results are then expressed in a closed form which is valid for nondegenerate as well as for degenerate semiconductors. The theory is applied explicitly to electronic noise in extrinsic and near-intrinsic crystals with and without recombination centers.

537.311.62 2694

**The Theory of the Anomalous Skin Effect in Metals for Obliquely Incident Radiation**—J. G. Collins. (*Appl. Sci. Res.*, vol. B7, no. 1, pp. 1–40; 1958.) The effective surface impedance of a metal varies with the direction of polarization of incident radiation in the upper visible and ultraviolet ranges. Formulas for refractive indexes, reflectivities, and principal angles at oblique incidence are derived in terms of two surface impedances. Experimental results are in good agreement with the theory.

537.5 2695

**The Microfield in Assemblies with Coulomb Interaction**—G. Ecker. (*Z. Phys.*, vol. 148, pp. 593–606; July 22, 1957.) Critical assessment of Holtsmark's theory in the light of the results of recent investigations. See also 384 of 1956.

537.5:538.63 2696

**Investigation of the Transverse Motion of Ions in a Discharge in a Strong Longitudinal Magnetic Field**—A. Zharinov. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1803–1810; August, 1957.) The influence of the gas pressure on the average transverse velocity of ions was investigated using a rotating probe. In an argon discharge, it was found that for pressures $<3\times10^{-3}$ mm Hg and in spite of a strong magnetic field of about 2300 oersteds, a considerable quantity of ions reached the side walls of the discharge chamber, so that an estimate could be made of the energy acquired by the ions in the radial electric field.

537.52 2697

**The Demonstration of Single Electron Avalanches and their Secondary Processes in Gases**—J. K. Vogel. (*Z. Phys.*, vol. 148, pp. 355–373; May 8, 1957.) Continuation of earlier experimental investigations [2413 of 1957 (Vogel and Raether)] on electron avalanches in oxygen, nitrogen, and air. An interpretation of the observed delay in the formation of avalanches in nitrogen and air is given.

537.523.3 2698

**Electrical Discharges between Coaxial Electrodes**—J. S. T. Looms. (*Nature, London,* vol. 181, pp. 696–697; March 8, 1958.) Luminous corona discharges occur when transient voltages are applied between a wire and a small coaxially mounted ring in air. Photographs show that the shapes of the discharges differ according to the polarity of the electrodes.

537.525 2699

**The Initiation of a V.H.F. Pulse Discharge in Neon**—V. E. Golant. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1482–1494; July, 1957.) An investigation carried out at 2800 mc with pulses of duration $10^{-6}$ seconds is described. The distribution function of the electron velocities, the kinetic coefficient of the electron interaction with the gas molecules, the HF conductivity, and the onset of discharge induced by a rectangular HF pulse are examined; the results are presented graphically.

537.53 2700

**Pulse Ionization Chamber as a Device for Simultaneous Investigation of the Energy and Angular Distributions of Charged Particles**—B. A. Bochagov, A. A. Vorob'ev, and A. P. Komar. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1575–1577; July, 1957.)

537.533 2701

**Small Oscillations in an Electron Beam**—R. V. Polovin and N. L. Tsintsadze. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1466–1473; July, 1957.) The stability conditions for the propagation of small-amplitude electromagnetic oscillations in noncompensated electron streams are examined and solutions for some particular cases are obtained.

537.533 2702

**On the Space-Charge Divergence of an Axially Symmetric Beam**—E. R. Harrison. (*J. Electronics Control*, vol. 4, pp. 193–200; March, 1958.) The usual assumptions made in estimating the space-charge effect are consistent with a coaxial, cylindrical conducting boundary. For small amounts of divergence a hyperbola solution is suggested; this may in some cases be as good as or better than the usual solution even when divergence is not small.

537.533 2703

**Small-Signal Power Conservation Theorem for Irrotational Electron Beams**—J. W. Klüver. (*J. Appl. Phys.*, vol. 29, pp. 618–622; April, 1958.) The theorem describes the balance between the RF kinetic and RF electromagnetic powers in a laminar beam; the thermal velocity distribution at the cathode is neglected. The kinetic power flow is expressed in terms of the Chu potential, the longitudinal component of the RF beam current and the equivalent longitudinal surface current on the beam boundary. See also 3701 of 1957 (Hans and Bobroff).

537.533.8 2704

**Variation of Secondary Emission with Primary Electron Energy**—B. K. Agarwal. (*Proc. Phys. Soc.*, vol. 71, pp. 851–852; May 1, 1958.) A simple formula is given, relating secondary emission to primary electron energy, which is more in agreement with experimental results for MgO and Ge than previous theoretical formulas.

537.56 2705

**Effective Cross-Sections of Electrostatic Interaction in Plasmas. Definitions**—M. Bayet. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1708–1710; November 13, 1957.) For calculations see *ibid.*, vol. 245, pp. 2493–2496; December 23, 1957. See also 1111 of 1958.

537.56 2706

**Effects of Electron-Electron Interactions on Cyclotron Resonances in Gaseous Plasmas**—R. C. Hwa. (*Phys. Rev.*, vol. 110, pp. 307–313; April 15, 1958.) From the Boltzmann-Fokker-Planck equation, a set of equations is derived and solved numerically. The results indicate that the real part of the electrical conductivity of the plasma (power absorption) is reduced by electron-electron interaction at the peak of resonance, and the width of resonance is increased.

537.56 2707

**Nonlinear Phenomenological Theory of Plasma Oscillations**—L. Gold. (*J. Electronics Control*, vol. 4, pp. 219–226; March, 1958.) Damped oscillations are shown to arise under certain conditions; the intensity of the standing waves being augmented by collisions with a loss of efficiency. In general, increasing current and plasma temperature tend to promote oscillations, while the role of plasma density is more complex. The influence of a magnetic field in the limiting case of no damping is also investigated.

538.3:530.12 2708

**Completely Integrable Singular Electromagnetic Field**—L. Mariot. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1386–1388; October 21, 1957.) Derivation of expressions for the components of the completely integrable singular electromagnetic tensor with reference to Maxwell's equations.

538.524 2709

**Induction by an Oscillating Magnetic Dipole over a Two-Layer Ground**—J. R. Wait. (*Appl. Sci. Res.*, vol. B7, no. 1, pp. 73–80; 1958.) Expressions for the mutual electromagnetic coupling between two small loops and for the self-impedance of a loop over a two-layer earth are derived.

538.566:531.51:530.12 2710

**Effect of a Gravitational Field, due to a Rotating Body, on the Plane of Polarization of an Electromagnetic Wave**—N. L. Balazs. (*Phys. Rev.*, vol. 110, pp. 236–239; April 1, 1958.) "It is shown that for electromagnetic waves the gravitational field of a rotating body acts as an optically active medium. Thus, the plane of polarization of the wave rotates while it passes through this field. The effect is small. The angle of rotation due to the gravitational field of the sun is about $10^{-12}$ radian."

538.566:535.42 2711

**Approximate Calculations of the Diffraction of Plane Electromagnetic Waves by some Metallic Bodies: Part 1**—P. Ya. Ufimtsev. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1840–1849; August, 1957.) A new approximate method of calculation is described which is applicable to the diffraction of electromagnetic waves by wedges or strips. The method applies to wavelengths much smaller than the linear dimensions of the diffracting body.

538.566:537.56 2712

**Basic Microwave Properties of Hot Magnetoplasmas**—J. E. Drummond. (*Phys. Rev.*, vol. 110, pp. 293–306; April 15, 1958.) The usual conductivity tensor of a uniform plasma in a uniform static magnetic field is generalized to include four effects of random motion of plasma electrons. The results are applied to the evaluation of the index of refraction for microwave signals.

538.569.4:538.22:537.228 2713

**Investigations of the Paramagnetic Nuclear Resonance Absorption in a Capacitor Field**—U. Gersch and A. Lösche. (*Ann. Physik., Leipzig.*, vol. 20, pp. 167–172; July 15, 1957.) The advantages and disadvantages of using a capacitor field for high-resolution nuclear induction spectroscopy are briefly outlined.

538.569.4:539.14.098 2714

**Theory of Saturation in Nuclear Magnetic Resonance**—G. Vojta. (*Z. Naturf.*, vol. 12a, pp. 282–294; April, 1957.)

539.2 2715

**Energy Band Splitting and Inter-band Terms in the Dislocation of Lattice Atoms in a Solid**—A. Haug and A. Schönhofer. (*Z. Phys.*, vol. 148, pp. 513–526; June 22, 1957.)

539.2:537.226 2716

**On the Theory of a Fast Polaron**—Yu. I. Gorkun. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1764–1769; August, 1957.) Expressions for the dependence of the polaron energy on its initial velocity are obtained. In connection with polarons, the breakdown voltages for ionic dielectrics are also examined. Results of investigations on alkali halide crystals are tabulated.

539.2:538.222 2717

**Spin-Lattice Relaxation**—M. W. P. Strandberg. (*Phys. Rev.*, vol. 110, pp. 65–69; April 1, 1958.) It is pointed out that phonon relaxation times can be the dominant quantity measured in the usual saturation spin-lattice relaxation measurements. The analysis indicates how pulse measurements may be used to evaluate the actual spin-lattice relaxation time independently of the phonon relaxation time.

539.2:548.0 2718

**One-Dimensional Impurity Bands**—M. Lax and J. C. Phillips. (*Phys. Rev.*, vol. 110, pp. 41–49; April 1, 1958.) "The density of states of one-dimensional crystals consisting of $\delta$ functions randomly distributed has been calculated on the IBM 650 computer. The chains contained 500–1000 impurity atoms, and the most probable error in the integrated density of states at various energies was estimated to be at most $\frac{1}{2}$ per cent. Calculations were performed for various values of the parameter $\epsilon = n/\kappa_0$, where $n$ is the density of atoms and $\kappa_0$ the attenuation constant appropriate to the isolated bound state. The results at different densities are compared with those obtained from various physical models."

539.2:548.0 2719

**The "Spur" [trace] Method in the Problem of the Exciton**—I. M. Dykman. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1731–1743; August, 1957.) The excitons in ionic crystals are examined. The interaction of electrons and holes with lattice vibrations is considered. It is shown that the change of energy at low temperatures is primarily determined by the weakening of the interaction of charged particles with the field of polarized vibrations when the temperature rises without increase of kinetic energy. The effective mass of the exciton is calculated. See also 3124 of 1957 (Dykman, *et al.*) and 2796 of 1957.

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5 2720

**The Initial Radius of Meteoric Ionization Trails**—L. A. Manning. (*J. Geophys. Res.*, vol. 63, pp. 181–196; March, 1958.) Kinetic theory is applied to the formation of regions of ionized and neutral atoms of meteoric material about the path of a meteor. It is found that the high initial velocity of the diffusing particles causes the trail to reach an "initial radius" quickly, and normal diffusion then ensues. A reflected signal may be computed as if the initial radius (14 mean free paths) were reached instantaneously.

523.5:621.396.11.029.62 2721

**The Random Occurrence of Meteors in the Upper Atmosphere**—T. J. Keary and H. J. Wirth. (*J. Geophys. Res.*, vol. 63, pp. 67–75;

March, 1958.) The distribution of time intervals between bursts of 43.5-mc signals over a 690-km path was studied statistically, using data obtained in two periods of two hours (778 and 446 bursts, respectively). Results were consistent with forward-scattering from meteor trails produced by random entry of meteors into the atmosphere.

523.74 2722

**Identification of $M$-Regions on the Sun**—K. Toman. (*Nature, London*, vol. 181, pp. 641–642; March 1, 1958.)

523.752 2723

**The Duration of Emission and the Slope of the Pulse Spectrum of Solar Ultraradiation during the Chromospheric Eruption of 23/2/1956**—G. Pfotzer. (*Ann. Physik., Leipzig*, vol. 20, pp. 26–41; July 15, 1957.) Recordings made at various stations are analyzed and discussed in relation to various theoretical models. Fifty-two references.

523.755:523.164.32 2724

**The Calculation of the Centre-Limb Variations and the One-Dimensional Intensity Profiles at $\lambda = 20$ cm and $\lambda = 60$ cm for a Rotationally Symmetric Corona Model at Constant Temperature**—G. Wallis. (*Z. Naturf.*, vol. 12a, pp. 337–345; April, 1957.) The calculated results are compared with those obtained from measurements by Christiansen and Warburton (1706 of 1956) and Swarup and Parthasarathy (1707 of 1956).

550.385:523.75 2725

**Geomagnetic Disturbances associated with Solar Flares with Major Pre-maximum Bursts at Radio Frequencies $\lesssim 200$ Mc/s**—H. W. Dodson and E. R. Hedeman. (*J. Geophys. Res.*, vol. 63, pp. 77–96; March, 1958.) A close association is found between solar flares in the early phase of which radio noise at frequencies $\lesssim 200$ mc is received, and sudden-commencement ionospheric storms on the earth. It is suggested that this RF emission may be from the sun's outer atmosphere and corona and thus may indicate which solar flares are accompanied by the ejection of storm-producing particles. Although flare data are incomplete, the proportion of flares having "major early bursts" is estimated at $<10$ per cent, and the number of flares is comparable to the number of ionospheric storms not identifiable with well-established 27-day recurrent series. An average time delay of $2\frac{1}{2}$ days occurs between flare and geomagnetic disturbance, and the intensity of the disturbance is related to the position of the flare on the sun's disk.

550.389.2:629.19 2726

**Progress of Sputnik 2 (1957$\beta$)**—D. G. King-Hele. (*Nature, London*, vol. 181, pp. 738–739; March 15, 1958.) Estimates of the orbital period, semi-major axis, and eccentricity on November 9, 1954, March 2, 1958, and two intermediate dates are given. These are based on observational data from different sources.

550.389.2:629.19 2727

**Determination of Orbital Characteristics of an Earth Satellite from Single-Station Radio-Transit Observations**—G. Grant, A. L. Jones, R. W. Burhans, P. S. Fay, and D. Frazier. (*Nature, London*, vol. 181, pp. 900–901; March 29, 1958.) Meridian observations of the satellite 1958 $\alpha$ have been made by means of an interferometer located at Cleveland, Ohio. Because of the generally low altitude of the satellite at this station horizontal dipoles were replaced by commercial Yagis.

551.510.535 2728

**The Mesopause Region of the Ionosphere**—J. B. Gregory. (*Nature, London*, vol. 181, pp. 753–754; March 15, 1958.) Observations have been made at 1.75 mc with pulse sounding apparatus at Christchurch, New Zealand, since early in 1955. Initial results (see 1433 of 1957) are confirmed. Extended observations indicate the continuous existence of ionization throughout a range of heights from about 80 to 100 km.

551.510.535 2729

**New Rocket Measurement of Ionospheric Currents near the Geomagnetic Equator**—L. J. Cahill, Jr. and J. A. Van Allen. (*J. Geophys. Res.* vol. 63, pp. 270–273; March, 1958.) Rocket-borne magnetometer measurements indicating current sheets at heights of 97–110 km and 118–121 km are described. Comparison with other data indicate that at 121 km only half the total current system had been penetrated.

551.510.535 2730

**Ionosphere Electron-Density Measurements with the Navy Aerobee-Hi Rocket**—J. E. Jackson and J. C. Seddon. (*J. Geophys. Res.*, vol. 63, pp. 197–208; March, 1958.) Electron densities were measured at heights between 80 km and 260 km above New Mexico by the Doppler-shift method in which the beat note between a 7.75-mc signal and a reference signal at 46.5 mc was recorded. The results, corrected for obliquity effects, confirm the general structure of the ionosphere previously measured, and are consistent with simultaneous $P'f$ records; the ionosphere remains dense between $E$ and $F_2$ regions. Sporadic $E$ was associated with a sharp spike in the distribution at 101 km, approximately 1 km thick.

551.510.535 2731

**Differential Absorption in the $D$ and Lower $E$ Regions**—J. C. Seddon. (*J. Geophys. Res.*, vol. 63, pp. 209–216; March, 1958.) A method of measuring electron densities in the $D$ region is described, in which use is made of the Faraday effect in rocket flights at White Sands, New Mexico. At noon on a day of high absorption, a value of 2000 electrons/cm$^3$ was obtained for an altitude of 76 km.

551.510.535:523.5 2732

**Concerning Ionospheric Turbulence at the Meteoric Level**—H. G. Booker. (*J. Geophys. Res.*, vol. 63, pp. 97–107; March, 1958.) A discussion on the application of fluid mechanics to meteoric phenomena is continued, with particular reference to a "rough trail paradox," which concerns the relative turbulent velocities of large and small eddies. The paper is mainly concerned with the relative merits of work by Booker and Cohen (1417 and 1441 of 1957) and by Manning and Eshleman (111 of 1958) regarding the explanation of radar echo fading.

551.510.535:523.75 2733

**Solar-Flare Effect in the $F_2$ Layer of the Ionosphere**—C. M. Minnis and G. H. Bazzard. (*Nature, London*, vol. 181, pp. 690–691; March 8, 1958.) $\Delta f$ is plotted as a function of local mean time, where $\Delta f$ is the difference between the measured critical frequency and the "normal" value based on that measured one hour previously. The $\Delta f$ plot for the period of the intense solar flare of February 23, 1956 shows a positive "pulse" of amplitude 1.1 mc followed by a second smaller pulse 5 hours later. An analysis of the statistics of the fluctuations in $\Delta f$ has been made.

551.510.535:523.75 2734

**Medium-Frequency Observations of the Lower Ionosphere during Sudden Disturbances**—J. B. Gregory. (*J. Geophys. Res.*, vol. 63, pp. 273–275, March, 1958.) Records obtained during S. I. D.'s by pulse sounding at 1.75 mc are analyzed in detail. The observed behavior gives support to the theory of Friedman and Chubb (*The Physics of the Ionosphere*, pp. 58–62; 1955.), that soft X rays and not Lyman-$\alpha$ radiation are responsible for S.I.D.'s.

551.510.535:550.385 2735

**Variations in the Height of Ionospheric Layers during Magnetic Storms**—E. Tandberg-Hanssen. (*J. Geophys. Res.*, vol. 63, pp. 157–160; March, 1958.) Statistical work carried out on Washington ionospheric data for 1952–1956 and magnetic planetary $K_p$ figures from CRPL publications, shows that the $E$ layer remains unchanged in height, while the $F_1$ layer rises during storms. Application to Parker's theory (1422 of 1957) gives 100–200 km as the height where storm-associated solar energy is absorbed.

551.510.535:551.515.2 2736

**An Apparent Ionospheric Response to the Passage of Hurricanes**—S. J. Bauer. (*J. Geophys. Res.*, vol. 63, pp. 265–269; March, 1958.) Evidence is given for the association of the passage of a hurricane with a departure of the critical frequency of the $F_1$ layer from its monthly mean value. The four hurricanes discussed resulted in rises in critical frequency of up to 2 mc. A possible mechanism is suggested.

551.594.6 2737

**Radio Noise from Lightning Discharges**—F. Horner and C. Clarke. (*Nature, London*, vol. 181, pp. 688–690; March 8, 1958.) Records obtained at Slough during two local thunderstorms in July and August, 1957, are reproduced including simultaneous recordings on 11 mc and 6 kc with bandwidths 300 and 200 cps, respectively.

551.594.6 2738

**Between the Atmospherics**—G. Reber. (*J. Geophys. Res.*, vol. 63, pp. 109–123; March, 1958.) An examination is made of the background cosmic radiation between atmospherics at a frequency of 520 kc. Records are explained in terms of an "ionospheric shutter" operated by two mechanisms: $D$-region absorption by day, and shift of coupling level between ordinary and extraordinary modes relative to the gyro-level at night. Observations of precipitation static and local atmospherics are also described.

550.389.2 2739

**Annals of the International Geophysical Year: Vol. 3—Parts 1–4 [Book Review]**—Pergamon Press, London and New York, 381 pp., 1957. (*Nature, London*, vol. 181, pp. 726–727; March 15, 1958.) The first volume to be published of a series of instruction manuals. Titles of the parts of Vol. 3 are: "Ionospheric Vertical Soundings," "Measurement of Ionospheric Absorbtion," "The Measurement of Ionospheric Drifts," and "Miscellaneous Radio Measurements."

## LOCATION AND AIDS TO NAVIGATION

621.396.9 2740

**Doppler Effect in Radio and Radar**—N. M. Rust. (*Wireless World*, vol. 64, pp. 304–307; July, 1958, pp. 373–377; August, 1958.) The general principles of the Doppler effect are explained; it is shown how directional discrimination can be obtained using phase-sensitive detectors. Various practical applications are described.

621.396.93 2741

**Dectra: a Long-Range Radio-Navigation Aid**—C. Powell, (*J. Brit. IRE*, vol. 18, pp. 277–290; May, 1958. Discussion, pp. 291–292.) The tracking and ranging functions of the system are discussed with reference to the time-sharing technique on which the tracking pattern is based. The receiving and display equipment is described and details are given of the transmitting stations which are common to the Dectra and Decca services. Accuracy and performance are considered.

621.396.932.1:621.396.677.53 2742

**The Polarization Direction-Finder**—J. Grosskopf and K. Vogt. (*Nachrtech. Z.*, vol. 10, pp. 572–579; November, 1957.) Report on experimental investigations made in 1944 on behalf of the German navy on a SWDF system with a combined dipole and loop antenna. Three different arrangements are considered: a) vertical loop with vertical dipole, b) horizontal loop with horizontal dipole, and c) vertical loop with horizontal dipole. The theory of operation of the system is detailed and diagrams of phase and amplitude difference as a function of azimuth angle are given for various types of polarization. A combination of arrangements a) and b) is the most generally useful. Interference due to the incidence of two waves is also considered. The polarization type of direction finder can provide results as accurate as those obtained by the Adcock system with the additional advantage of a much more compact antenna arrangement.

621.396.933.2 2743

**Long-Range Radio Beacons**—K. Lutz. (*Brown Boveri Rev.*, vol. 44, pp. 451–452; October, 1957.) A 10-kw radio beacon for aircraft and marine navigation is described. It operates in the 200–415-kc band and the transmitter can be used for telephony.

621.396.933.2 2744

**On the Accuracy of Determining Position by Radio Navigation Methods**—A. G. Saibel'. (*Radiotekhnika, Mosk.*, vol. 12, pp. 62–66; May, 1957.) Various methods for assessing accuracy are reviewed and compared on the basis of distribution functions of error probabilities. It is suggested that this accuracy should be characterized by the mean-square error in position.

621.396.96:551.515.3 2745

**R.H.I. Radar Observation of a Tornado**—J. Schuetz and G. E. Stout. (*Bull. Amer. Met. Soc.*, vol. 38, pp. 591–595; December, 1957.)

621.396.967:621.396.932 2746

**The Shore-Based Radar System for the New Rotterdam Waterway**—N. Schimmel. (*Tijdschr. ned. Radiogenoot.*, vol. 22, pp. 59–86; March, 1957. In English.)

### MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 2747

**Photoconductivity**—D. A. Wright. (*Brit. J. Appl. Phys.*, vol. 9, pp. 205–214; June, 1958.) The general process of photoconductivity is reviewed, and the preparation and properties of photoconducting materials are described, in particular CdS. The effects on sensitivity of defects in the crystal lattice and of the nature of impurities are discussed. Applications are outlined. Thirty-four references.

535.215:537.311.33 2748

**Diffusion of Charge Carriers in Photoconductors taking account of Local Levels**—J. Auth. (*Ann. Physik, Leipzig*, vol. 20, pp. 210–214; July 15, 1957.) A model is derived for an *n*-type photoconductor and approximate solutions of the diffusion equations are obtained.

535.215:546.482.21 2749

**The Influence of Dielectric After-Effects on Conduction in CdS Single Crystals in the Region of Breakdown Field-Strength**—K. W. Böer and U. Kümmel. (*Ann. Physik., Leipzig.*, vol. 20, pp. 303–314; July 15, 1957.) See also 135 of 1956 and 3792 of 1956 (Böer, *et al.*).

535.215:546.817.231 2750

**The Effect of Various Gases and Vapours on the Semiconductor Properties of Vapour-Deposited Lead Selenide Films**—H. Gobrecht, F. Niemeck, and K. E. Boeters. (*Z. Physik*, vol. 148, pp. 281–297; May 8, 1957.) Tests were made on specimens prepared by the method outlined in 2634 of 1955 (Gobrecht, *et al.*) to determine the effect of Hg and I vapors on photoconductivity and dark resistance. Measurements were also carried out with air, oxygen, nitrogen, hydrogen, and argon to find the relation between photoconductivity and gas pressure.

535.35:534–8 2751

**The Effect of Ultrasonic Radiation on the Luminescence of Zinc Sulphide Fluorescent Screens under Continuous Excitation by Light**—M. Leistner. (*Ann. Physik, Leipzig*, vol. 20, pp. 129–141; July 15, 1957.) Full report and analysis of test results previously noted in 3158 of 1957 (Leistner and Herforth).

535.376 2752

**Enhancement by Electric Fields of the Sensitivity of Certain Luminescent Products to X Rays, and "Photoelectroluminescence"**—G. Destriau. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1797–1800; November 18, 1957.) Research on $(CdS_3ZnS)$-Mn does not support the theory of Cusano (2980 of 1955) and Williams (2981 of 1955).

535.376 2753

**Sensitization, by Traces of Gold, of Products with an Electroenhancement Effect**—G. Destriau. (*C.R. Acad. Sci., Paris*, vol. 245 pp. 1913–1916; November 25, 1957.) The addition of traces of Au to the Mn activator in CdS-ZnS mixtures increases both the enhancement ratio, defined as the ratio of brightness under combined X-ray and electric-field excitation to that under X-ray excitation alone, and the field sensitivity.

537.226/.228.2:546.431.824–31 2754

**Two Experiments on the Electromechanical Characteristics of Barium Titanate Ceramics in the Curie Region**—G. Schmidt. (*Z. Physik*, vol. 148, pp. 314–320; May 8, 1957.) The results are discussed of further tests on thickness variation as a function of polarization and field strength, a) with a superimposed 400-cps field, and b) at field strengths up to 3 kv/cm. See also 465 of 1957.

537.226/.228.1:546.431.824–31 2755

**Piezoelectric and Dielectric Characteristics of Single-Crystal Barium Titanate Plates**—A. H. Meitzler and H. L. Stadler. (*Bell Sys. Tech. J.*, vol. 37, pp. 719–738; May, 1958.) The dielectric constant of *c*-domain $BaTiO_3$ single-crystal plates has been measured as a function of their average polarization, using alternating voltages much smaller than the coercive voltage. At frequencies well above thickness resonance the dielectric constant has a maximum at zero polarization. The piezoelectric output voltage of a single crystal subjected to a recurrent strain pulse of constant amplitude is not exactly proportional to its average polarization. Plate-shaped single crystals have a significantly lower dielectric constant and smaller capacitance ratio when used as resonators in the thickness-extensional mode than similar resonators of ceramic $BaTiO_3$.

537.226/.227:546.431.824–31 2756

**High Permittivity of Some Solid Solutions with Ferroelectric Properties**—W. A. Bokov. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1784–1793; August, 1957.) Investigations of the temperature dependence of the dielectric constant and the loss angle of solid solutions of the type: $(Ba,Sr)TiO_3$, $Ba(Ti,Sn)O_3$, and $Ba(Ti,Zr)O_3$ in weak fields. Results are presented graphically.

537.226/.227:546.431.824–31 2757

**Some Anomalies of the Hysteresis Loop in Ceramic Barium Titanate and Piezolan**—E. Hegenbarth. (*Ann. Physik, Leipzig*, vol. 20, pp. 20–25; July 15, 1957.) Analysis and discussion of hysteresis loop and $V/I$ oscillograms. See, *e.g.*, 3758 of 1956 (Heywang and Schöfer).

537.227:539.2 2758

**Appearance of Spontaneous Polarization in Crystals**—G. A. Smolenskiĭ. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1778–1783; August, 1957.) Ferroelectric active ions and chemical bonds in ferroelectrics and antiferroelectrics are considered. Some experimental results concerning the structure of electron shells occurring in the oxygen octahedrons of ferroelectrics containing no hydrogen are discussed.

537.227:546.431.824–31:621.318.57 2759

**Electrical Stability of $BaTiO_3$ Single Crystals at −195°C**—H. L. Stadler. (*J. Appl. Phys.*, vol. 29, pp. 743–744; April, 1958.) Crystals at room temperature, used as matrix-type digital storage systems exhibit a gradual loss of response with continuous switching sequences. This decay does not occur at −195°C and is not primarily dependent on crystal phase.

537.227:547.476.3 2760

**Ferroelectric Polarization Reversal in Rochelle Salt**—H. H. Wieder. (*Phys. Rev.*, vol. 110, pp. 29–36; April 1, 1958.) Besides the slow, lateral motion of *b* and *c*-domain walls, there is observed a fast reversal process characteristic of the nucleation and wall propagation in the orthorhombic *a* direction.

537.227:621.375.5:621.396.822 2761

**Noise of Cyclic Repolarization of Ferrelectrics**—I. A. Andronova. (*Doklady Akad. Nauk S.S.S.R.*, vol. 119, pp. 68–70; March 1, 1958.) Noise occurring in dielectric amplifiers due to cyclic repolarization is attributed to a ferroelectric domain structure. The temperature dependence of this noise is examined.

537.311.33 2762

**Semiconductors Again**—(*Wireless World*, vol. 64, pp. 339–343; July, 1958.) A nonmathematical explanation, from the energy-level point of view, of the properties of semiconductors.

537.311.33 2763

**Electrons, Holes, and Traps**—W. Shockley. (Proc. IRE, vol. 46, pp. 973–990; June, 1958.) "The statistics of recombination and of trapping of electrons and holes through traps of a single species are presented. The results of the Shockley-Read recombination theory are derived and more fully interpreted. A level of energy known as the equality level is introduced. When the Fermi level lies at this level, the four basic processes of electron capture, electron emission, hole capture, and hole emission all proceed at equal rates. Transient cases for large trap density are presented."

537.311.33 2764

**Recombination in Semiconductors**—G. Bemski. (Proc. IRE, vol. 46, pp. 990–1004; June, 1958.) The kinetics of hole-electron recombination, either direct or by means of recombination centers, are reviewed. The latter process accounts for recombination in Ge and Si, but the former becomes important in semiconductors with narrower energy gaps. Trapping and surface recombination are also considered in relation to volume recombination. Experimental methods of measuring lifetime are reviewed, and results are discussed in terms of the various recombination processes. One-hundred thirty-one references.

537.311.33 2765

**The Preparation of Semiconductor Devices by Lapping and Diffusion Techniques**—H. Nelson. (Proc. IRE, vol. 46, pp. 1062–1067; June, 1958.) Large semiconductor wafers can be processed to a point where they can be diced into numerous and identical devices. Lapping instead of etching is used for all shaping and the high degree of precision built into the lapping apparatus is passed on to all the devices. Unipolar, photo-unipolar, and bipolar transistors and negative-resistance devices have been made.

537.311.33 2766

**On Junctions between Semiconductors having Different Energy Gaps**—H. L. Armstrong. (Proc. IRE, 46, pp. 1307–1308; June, 1958.)

537.311.33 2767

**Thermodynamic Treatment of Electron Processes in Semiconductor Boundary Layers**—N. A. Müser. (*Z. Physik.*, vol. 148, pp. 380–390; May 8, 1957.) An interpretation of the processes occurring in *p-n* junctions is derived on the basis of thermodynamics. The principle is applied to a consideration of photoelectric efficiency and the process of rectification at a *p-n* junction.

537.311.33 2768

**Semiconductors considered as Ionized Media**—M. Demontvignier. (*Rev. gén. Élect.*, vol. 66, pp. 495–512; October, 1957.) An analogy is drawn between the theory of tetravalent semiconductors and the theory of electrolytes.

537.311.33 2769

**The Temperature Dependence of Mobility in Nonpolar Semiconductors**—D. Dorn. (*Z. Naturf.*, vol. 12a, pp. 18–22; January, 1957.) Bloch's theory is extended to allow for electron energy changes due to collision with thermal lattice vibrations. The resulting correction leads to an increase in mobility compared to the $T^{-3/2}$ law.

537.311.33 2770

**Measurements of Lifetime of Charge Carriers in Semiconductors**—M. I. Iglitsyn, Yu. A. Kontsevoĭ, V. D. Kudin, and A. A. Meĭer. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1414–1424; July, 1957.) A theoretical and experimental investigation based on the modulation of conductivity at the point-contact is presented. Formulas taking account of the diffusion and recombination at this point are derived.

537.311.33 2771

**Simple Methods for Investigating the Zone Structure of some Semiconductor Compounds**—V. E. Khartsiev. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1713–1722; August, 1957.) Some general expressions determining the band structure in semiconductors are derived. After a general survey of the one-dimensional problem, and with the help of matrix relations, three-dimensional lattice models, with Zn and NaCl types of structure, are examined.

537.311.33 2772

**Low-Temperature Anomalies in Impurity Semiconductors**—M. I. Klinger. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1915–1922; August, 1957.) Theoretical investigation of *p*-type and *n*-type semiconductors. See also 3184 of 1957.

537.311.33:061.3 2773

**All-Union Conference on the Theory of Semiconductors**—M. F. Deĭgen, I. M. Dykman, and K. B. Tolpygo. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1628–1642; July, 1957.) Summaries are given of some 40 papers read during the Conference at Kiev, October 9–13, 1956. The papers are grouped under the following headings: a) multielectron theory of solids, b) exciton processes in semiconductors, c) interaction of current carriers with the crystal lattice theory of polaron, d) theory of the local state of an electron in semiconductors, e) the band structure in semiconductors, f) magnetic properties of semiconductors, and g) phenomenological theory of semiconductors.

537.311.33:539.16 2774

**Irradiation of *P-N* Junctions with Gamma Rays: a Method for Measuring Diffusion Lengths**—R. Gremmelmaier. (Proc. IRE, vol. 46, pp. 1045–1049; June, 1958.) The short-circuit current in an irradiated *p-n* junction is given by the product of the electron charge, the generation rate ($g$) of minority carriers, and a quantity equal to the diffusion length if the junction position is suitably chosen; $g$ can be calculated for irradiation by $\gamma$ rays from a $Co^{60}$ source, and the short-circuit current measured. Diffusion lengths are observed up to $8\mu$ in GaAs and $130\mu$ in InP.

537.311.33:[546.28+546.289 2775

**Properties of Silicon and Germanium-II**—E. M. Conwell. (Proc. IRE, vol. 46, pp. 1281–1300; June, 1958.) Revision of an earlier paper (738 of 1953) giving the physical background of more recent advances and best current values of important physical quantities. One hundred seventeen references.

537.311.33:[546.28+546.289 2776

**Scattering of Holes in Germanium and Silicon**—G. E. Pikus. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1606–1609; July, 1957.) The lattice scattering of heavy and light holes within and between the two valence bands of Ge and Si is considered. The matrix elements and angular distribution for this scattering are examined and the relations of concentrations of light and heavy holes, and also of their respective mobilities, are tabulated.

537.311.33:[546.28+546.289 2777

**Formation of Junction Structures by Solid-State Diffusion**—F. M. Smits. (Proc. IRE, vol. 46, pp. 1049–1061; June, 1958.) "The diffusion of group III and group V impurities into germanium and silicon is reviewed. Observed and possible variations of the diffusion coefficient with concentration are discussed, followed by a summary of the diffusion coefficients and of solutions to the diffusion equation. Finally, methods for the evaluation of diffused layers and diffusion techniques are described."

537.311.33:[546.28+546.289 2778

**Galvanomagnetic Effects in n-Type Ge or n-Type Si Single Crystals in Strong Magnetic Fields**—M. I. Klinger and P. I. Voronyuk. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1609–1613; July, 1957.) A mathematical analysis is presented in which the electrical resistance and Hall constant of *n*-type semiconductors are examined.

537.311.33:[546.28+546.289 2779

**The Effects of Neutron Irradiation on Germanium and Silicon**—G. C. Messenger and J. P. Spratt. (Proc. IRE, vol. 46, pp. 1038–1044; June, 1958.) A theoretical expression is derived for the dependence of grounded-emitter current gain of a transistor on accumulated neutron dose. Observed changes in transistor parameters after irradiation are explained in terms of this theory, and in the case of Ge enabled the position of the recombination site in the forbidden band, and its capture cross sections for holes and electrons, to be determined.

537.311.33:546.28 2780

**Preparation of Pure Silicon by the Thermal Decomposition of Silane**—S. I. Kleshchevnikova, Ya. E. Pokrovskiĭ, and E. I. Rumyantseva. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1645–1648; August, 1957.) The method and apparatus are described and results presented graphically.

537.311.33:546.28 2781

**Evaluation of Surface Concentration of Diffused Layers in Silicon**—G. Backenstoss. (*Bell Sys. Tech. J.*, vol. 37, pp. 699–710; May, 1958.) A diffused layer in a semiconductor is characterized by the impurity distribution. A method for determining the surface concentration of diffused impurity layers is described. It is shown that the surface concentration can be found for the properties of the junction and calculations have been made for typical impurity distributions in silicon.

537.311.33:546.28 2782

**Inversion Boundary Layers on *p*-Type Silicon**—S. Müller. (*Z. Naturf.*, vol. 12a, pp. 112–122; February, 1957.) The formation in water vapor of an inversion layer in *p*-type Si is investigated and the conductivity of the layer is determined, which is of the order of $10^{-5}$–$10^{-6}\Omega^{-1}$. Two types of surface state are observed, one in which equilibrium with the conduction band is rapidly reached, and the other with relaxation times of 10–50 minutes. The density of the former states is much higher in Si than in Ge. See also 2434 of 1956 (Statz, *et al.*).

537.311.33:546.28 2783

**Measurement of Lifetime of Charge Carriers in Si Single Crystals**—M. I. Iglitsyn, Yu. A. Kontsevoĭ, and V. D. Kudin. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1425–1430; July, 1957.) The lifetime is evaluated by measuring the modulated conductivity in the region of the point-contact by passing two consecutive current pulses. The effect of temperature on the charge-carrier lifetime is investigated. The results seem to be in good agreement with the Shockley-Read theory (420 of 1953).

537.311.33:546.28 2784

**Evidence of Dislocation Jogs in Deformed Silicon**—W. C. Dash. (*J. Appl. Phys.*, vol. 29, pp. 705–709; April, 1958.)

537.311.33:546.28:548.5 2785

**Silicon Crystals Free of Dislocations**—W. C. Dash. (*J. Appl. Phys.*, vol. 29, pp. 736–737; April, 1958.) A brief description of a method for growing crystals free from detectable oxygen and without observable dislocations.

537.311.33:546.281.46 2786

**Properties of Silicon Carbide under Pulsed Conditions**—R. Goffaux. (*Rev. gén. Élect.*, vol. 66, pp. 463–472; September, 1957.) A model is proposed to explain the observed $I/V$ characteristic; explanations based on the thermal ionization of donor centers and on the tunnel effect are disputed. See 434 of 1954 (Teszner, *et al.*).

537.311.33:546.289 2787

**Energy Spectrum of Current Carriers in Semiconductors of the Germanium Type**—A. G. Samoĭlovich and K. D. Tovstyuk. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1753–1763; August, 1957.) A mathematical analysis is presented and the energy spectrum of current carriers of Ge and Si is examined. The energy spectrum of holes seems to depend not on the orbital spin interaction but on the distribution of clouds of valence electrons, that is, on the nature of chemical bonds. By a proper choice of wave functions, an electron energy spectrum can be obtained which is in agreement with experimental data.

537.311.33:546.289 2788

**Determination of Relaxation Time of Surface States in Germanium**—A. E. Yunovich. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1707–1712; August, 1957.) Results of measurements of the field effect in the frequency range 400 cps–80 kc on *n*-type Ge samples indicate the strong dependence of the relaxation time of surface states on the ambient atmosphere.

537.311.33:546.289 2789

**Direct Optical Transitions and Further Exciton Effects in Germanium**—G. G. Macfarlane, T. P. McLean, J. E. Quarrington, and V. Roberts. (*Proc. Phys. Soc., London*, vol. 71, pp. 863–866; May 1, 1958.) Measurements of absorption coefficient in Ge at temperatures in the range 20°K–291°K show a theoretically predicted absorption line, due to exciton production, at a photon energy less than $E_0$, the energy gap, by an amount $E_{ex}$, the binding energy of an exciton of zero wave vector. Values of $E_{ex}$ agree well with estimates based on the effective mass, but there is a marked discrepancy between the low-temperature values of $E_0$ and those obtained by Zwerdling, *et al.* (1449 of 1958) in work on the oscillatory magneto-absorption effect. See also 1463 of 1958.

537.311.33:546.289 2790

**Impact Ionization in Germanium Single Crystals in the Temperature Range 4.2°K–10°K**—C. Kinke and G. Lautz. (*Z. Naturf.*, vol. 12a, pp. 223–225; March, 1957.) The effect interpreted as impact ionization [see, *e.g.*, 754 of 1955 (Ryder, *et al.*)] is investigated as a function of temperature, purity of Ge, and transverse magnetic field strength.

537.311.33:546.289 2791

**Field Modulation of Liquid-Induced Excess Surface Currents on Germanium *p-n* Junctions**—W. T. Eriksen. (*J. Appl. Phys.*, vol. 29, pp. 730–733; April, 1958.) Experiments show that modulation is only possible for polar liquids and increases with decreasing temperature down to the melting point of the liquid. A qualitative explanation is discussed in terms of a model in which the charge carriers move in the liquid outside the semiconductor.

537.311.33:546.289:535.215 2792

**Change of Lifetime in Thin Germanium Plates under the Action of an External Electric Field and Adsorption**—V. I. Lyashenko. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1613–1615; July, 1957.) Experiments show that the photo-EMF and carrier lifetime in *n*-type and *p*-type Ge increase or decrease according to the direction of the applied field. The effects of the adsorption of liquid films such as acetone, alcohol, benzene, water, and vaseline oil are also investigated.

537.311.33:546.289:535.32 2793

**Optical Constants of Germanium: 3600 Å to 7000 Å**—R. J. Archer. (*Phys. Rev.*, vol. 110, pp. 354–358; April 15, 1958.) The optical constants, obtained from the ellipticity of reflected polarized light, show two maxima, and are consistent with the Kramers-Kronig relations.

537.311.33:546.289:537.32:538.63 2794

**The Magnetic Variation of Thermoelectric Power of Ge Single Crystals at Low Temperatures**—J. Erdmann, H. Schultz, and J. Appel. (*Z. Naturf.*, vol. 12a, pp. 171–174; February, 1957.) Results of measurements on pure *n*-type specimens are reported and briefly discussed. The changes of thermoelectric power as a function of magnetic field strength in the range 0–17 kg are plotted for 22.9°, 59.0°, and 82.4°K. See also 2796 of 1956 (Lautz and Ruppel).

537.311.33:546.47–31:546.824–31 2795

**Nonlinear ZnO-TiO$_2$ Semiconductors**—Kh. S. Valeev and M. D. Mashkovich. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1649–1651; August, 1957.) The electrical properties of $2ZnO–TiO_2$ are examined for concentrations of up to 40 per cent of TiO$_2$. Graphs are included which show, as a function of concentration, a) the specific resistance, measured with constant potential of 16 volts and b) the temperature coefficient of resistance in the internal 20–120°C. Up to 30 per cent of TiO$_2$, *n*-type conductivity was observed and above this, *p*-type conductivity.

537.311.33:546.49.241:538.63 2796

**Nernst—Ettingshausen Effect in Mercuric Telluride**—I. M. Tsidil'kovskiĭ. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1744–1752; August, 1957.) Experiments carried out in the range 125–600°K showed that the temperature dependence of the Nernst=Ettlingshausen effect could be explained by thermomagnetic theory. The temperature dependence of the electron and hole mobility was estimated. A quantitative confirmation of the theory was obtained in strong magnetic fields with equal current-carrier concentrations. Depending on the purity and polycrystalline content, HgTe at room temperature had a maximum electron mobility of $1.15\times10^4$cm$^2$/v second.

537.311.33:546.681.19 2797

**Electron Bombardment of *p-n* Barrier Layers in GaAs**—H. Pfister. (*Z. Naturf.*, vol. 12a, pp. 217–222; March, 1957.) The changes of EMF and short-circuit current due to electron bombardment at different intensities are investigated. These effects can be used for the measurement of electron beam intensity up to 315 kev before radiation damage sets in.

537.311.33:546.682.19:538.63 2798

**The Magnetic Resistance Change in InAs**—H. Weiss. (*Z. Naturf.*, vol. 12a, p. 80; January, 1957.) The resistance of a Corbino disk of InAs increased 5.5-fold in a field of 10,000 G. For a long single-crystal rod the resistance change amounted to 2.4 per cent at 10,000 G. For tests on InSb see 143 of 1955 (Weiss and Welker).

537.311.33:546.682.86:537.312.8 2799

**The Transverse Magnetoresistance Effect in Indium Antimonide**—C. H. Champness. (*J. Electronics Control*, vol. 4, pp. 201–218; March, 1958.) "Measurements have been made on a wide range of nearly single crystal specimens at different temperatures. While most of the results can be explained from the measured carrier concentrations and Hall mobilities assuming lattice and impurity scattering, it is found that the magnetoresistance at liquid air temperature is larger than expected."

537.311.33:546.682.86:539.23 2800

**Preparation and some Electrical Properties of Thin Films of InSb**—C. Paparoditis. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1526–1528; October 28, 1957.) Films of *n*-type material 200–1700 Å thick were deposited on mica by evaporation in vacuo followed by reheating in argon. Hall effect and resistivity were measured and the structure of some samples was studied by X rays and by electron microscope. The mean free path in samples reheated to 280°C was found to be much less than that in the bulk material and also less than the thickness of the samples.

537.311.33:546.682.86:539.23 2801

**Theoretical Results relating to Thin Films of Indium Antimonide**—A. Colombani and J. Launay. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1607–1608; November 4, 1957.) For previous work see 2469 and 2470 of 1958.

537.311.33:546.873.241:537.323 2802

**Thermoelectric Properties of Bismuth Telluride and its Alloys**—D. A. Wright. (*Nature, London*, vol. 181, p. 834; March 22, 1958.) Progress since 1954 [see 1465 of 1955 (Goldsmid and Douglas)] in the production of pure *p* and *n*-type Bi$_2$Te$_3$ is reported. A maximum temperature difference of 65°C at a mean temperature difference of 65°C at a mean temperature of 17°C and Hall electron mobilities as high as 300 cm$^2$/v second have been obtained with these materials, and a maximum temperature difference of 80°C at the same mean temperature has been obtained by combinations of alloys of analogous materials.

537.311.33:548.5 2803

**Oriented Growth and Definition of Medium-Angle Semiconductor Bicrystals**—H. F. Mataré and H. A. R. Wegener. (*Z. Physik.*, vol. 148, pp. 631–645; July 22, 1957. In English.) The physical and metallurgical procedure in the preparation of semiconductor bicrystals is described, methods of seed orientation are given and precision limits are discussed. High-precision boundaries with tilt angle between 1° and 25° can be grown; a number of microphotographs of grown grain boundary structures are shown.

537.311.33:621.314.7 2804

**The Status of Transistor Research in Compound Semiconductors**—D. A. Jenny. (PROC. IRE, vol. 46, pp. 959–968; June, 1958.) The most promising semiconducting materials likely to compete with Ge and Si in transistor fabrication are among the group III-V and group IV-IV compounds. On the basis of performance at high temperatures and high frequencies, it is shown that, of compounds evaluated to date, GaAs and InP are the most promising, while AlSb, GaP and SiC will be useful at higher temperatures, at the cost of HF performance. Two new methods of junction preparation are described, namely surface diffusion and the formation of a wide-gap junction, which can be used to increase emitter efficiency. InP and GaAs transistors have been demonstrated, and electron lifetimes in the material estimated from measurements on them.

537.311.33+535.215]:621.396.822 2805

**Noise In Semiconductors and Photoconductors**—K. M. van Vliet. (PROC. IRE, vol. 46, pp. 1004–1018; June, 1958.) A survey of theory and experimental results relating to generation-recombination noise in semiconductors and photoconductors, 1/*f* noise in single crystals, and modulation noise in granular materials. One hundred seven references.

538.221 2806

**The Dependence of the Coercive Force on Dislocation Density**—Z. Málek. (*Z. angew. Phys.*, vol. 9, pp. 279–280; June, 1957.) Critical assessment of Kersten's theory (1825 of 1957) in the light of recent measurements, followed by Kersten's comment (*ibid.*, pp. 280–281).

538.221 2807

**The Effect of Dislocations on the Initial Permeability of Nickel in the Recrystallized and in the Plastically Deformed State**—M. Kersten. (*Ann. Physik., Leipzig.*, vol. 20, pp. 337–344; July 15, 1957.) Further discussion of the theory outlined in 1825 of 1957 with reference to experimental findings.

538.221 2808

**Magnetization Curves of Tubular Specimens of Nickel under Torsion and Pressure**—K. Strnat. (*Z. Naturf.*, vol. 12a, pp. 76–79; January, 1957.)

538.211:538.24 2809

**Radiation Magnetization**—C. H. Becker. (*Z. Physik.*, vol. 148, pp. 391–401; May 8,

1957. In English.) "Radiation magnetization represents a new electron induction effect within ferrites resulting in real permanent magnetization, dynamically induced and detected by means of microwaves."

538.221:621.318.134 2810

**Domain Patterns on a Single Crystal of Manganese Ferrite**—L. F. Bates, D. J. Craik, and P. M. Griffiths. (*Proc. Phys. Soc.*, vol. 71, pp. 789–796; May 1, 1958.) Domain patterns on a cleaved surface were studied by optical and electron microscopy, using a colloid film technique. Separate fine and coarse patterns were observed, which are believed to represent independent domain structures, due, respectively, to internal domain structure and to a surface effect produced by cleavage.

538.221:621.318.134 2811

**Magnetic and Crystallographic Properties of Substituted Yttrium-Iron Garnet, $3Y_2O_3 \cdot xM_2O_3.(5\text{-}x)Fe_2O_3$**—M. A. Gilleo and S. Geller. (*Phys. Rev.*, vol. 110, pp. 73–78; April 1, 1958.) A solid solution of Y-Fe garnet with Y-Ga or Y-Al garnet was formed over the entire range of composition, the lattice-constant variation being nearly linear. The trivalent ions, $Sc^{3+}$, $In^{3+}$ and $Cr^{3+}$ were substituted for $Fe^{3+}$ to a limited extent. The effect of the substitutions on the magnetic moment and Curie temperature is described.

538.221:621.318.134 2812

**Interpretation of Variations with Temperature of the Ferrimagnetic Resonance Fields in Gadolinium Garnet**—J. Paulevé. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1604–1607; November 4, 1957.) Results of recent experimental work on pure material [see 538 of 1958 (Calhoun, *et al.*)] supplement previous work (3214 of 1957) and show reasonable agreement with theoretical hyperbolic curves.

538.221:621.318.134:621.372.413:621.317.411 2813

**Frequency Shifts in Cavities with Longitudinally Magnetized Small Ferrite Disks**—H. Seidel and H. Boyet. (*Bell Sys. Tech. J.*, vol. 37, pp. 637–655; May, 1958.) The tensor permeability components of a magnetized ferrite can be found from the frequency shift produced by the ferrite in a resonant cavity. Mathematical expressions are found for the permeability tensor for any natural mode in a cavity. Examples are given for various cavities.

538.614:539.23:621.317.44 2814

**Investigation of the Magnetic Properties of Vapour-Deposited Iron Films by means of the Faraday Effect**—L. Reimer. (*Z. Physik.*, vol. 148, pp. 527–532; June 22, 1957.) Note on the method outlined in 3592 of 1957 and further experimental results.

538.632 2815

**Hall Coefficient of Technically Pure Metals from 80°K to 800°K**—V. Frank. (*Appl. Sci. Res.* vol. B6, no. 5, pp. 379–387; 1957, and vol. B7, no. 1, pp. 41–51; 1958.)

Part 1: Results for Cu, Ag, Au, Pd, and Pt.

Part 2: Results for Zr, W, Mo, Ta, Nb, and Al. Survey of results for the 4*d* and 5*d* transition group of metals.

621.315.61 2816

**The Electrical Conductivity of Solid Organic Insulators**—N. Riehl. (*Ann. Physik., Leipzig.*, vol. 20, pp. 93–128; July 15, 1957.)

621.315.61:537.221 2817

**Triboelectricity and Electron Traps in Insulating Materials: some Correlations**—E. Fukada and J. F. Fowler. (*Nature, London*, vol. 181, pp. 693–694; March 8, 1958.) Some correlation is found between triboelectric properties and the distribution of electron traps as determined by a study of X-ray-induced conductivity [see 848 of 1957 (Fowler)].

621.315.61:538.566.029.6 2818

**Low-Reflection Dielectric Walls for Microwaves**—H. Meinke. (*Nachrtech. Z.*, vol. 10, pp. 551–558; November, 1957.) Methods of obtaining a small reflection coefficient over a narrow as well as a wide band of frequencies are reviewed. The properties of dielectric media, particularly those containing graphite and iron powder, are discussed. Twenty-eight references.

621.315.612.6 2819

**Preparation and Investigation of Dielectric Properties of a Group of Glasses with Increased permittivity**—G. I. Skanavi and A. M. Kashtavova. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1770–1777; August, 1957.) Three groups of glasses were investigated: boron, tellurite, and boron lead glasses. Best results were obtained with 24 per cent $TiO_2$, 54.4 per cent PbO glasses giving a dielectric constant of 35 and breakdown voltage of $2\times10^6$ v/cm. Results are shown in graphical and tabular form.

621.315.612.6:537.226.31 2820

**Nature of Dielectric Losses in Sodium Aluminosilicate Glasses**—V. I. Ioffe. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1454–1461; July, 1957.) An investigation of silicate and borate glasses in the temperature range 20–290°K at 230, 1000 and 1700 kc. Dielectric losses were observed to decrease with increasing oxygen content. The results are presented graphically.

## MATHEMATICS

512.831:518.2 2821

**Tables for Diagonalizing Second-Order Matrices**—R. E. Trees and C. D. Coleman. (*J. Res. Natl. Bur. Stand.*, vol. 60, pp. 201–214; March, 1958.) "Sets of tables are given to facilitate the evaluation of the eigenvalues and eigenvectors of second-order matrices."

512.831:621.372.6 2822

**Matrices all of whose Elements and Subdeterminants are 1, −1 or 0**—I. Cederbaum. (*J. Math. Phys.*, vol. 36, pp. 351–361; January, 1958.) See also 2009 of 1958.

517.512.2 2823

**The Relationship of Physical Applications of Fourier Transforms in Various Fields of Wave Theory and Circuitry**—E. F. Bolinder. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 153–158; April, 1957. Abstract, PROC. IRE, vol. 45, p. 1036; July, 1957.)

517.512.4:518.2 2824

**Table of First 700 Zeros of Bessel Functions—$J_l(x)$ and $J'_l(x)$**—C. L. Beattie. (*Bell Sys. Tech. J.*, vol. 37, pp. 689–697; May, 1958.) The zeros of the Bessel functions and Bessel function derivatives are identified by standard waveguide notation which also serves as a code for more general mathematical applications.

518.6:621.372.2 2825

**Application to Electrodynamic Problems of an Approximation of a Logarithm by a Power Law**—W. Rehwald and O. Zinke. (*Arch. elekt. Übertragung*, vol. 11, pp. 397–402; October, 1957.) The function $\log_e\chi$ is approximated by a power law of the form $A\chi^c$. The method is applied to the problem of electromagnetic wave propagation along a bare wire of finite conductivity (Somerfeld line) and along a helical conductor.

## MEASUREMENTS AND TEST GEAR

529.78:621.374:621.314.7 2826

**Transistor Chopper drives Accurate Clock**—R. H. Williams. (*Electronics*, vol. 31, pp. 64–65; May 23, 1958.) A 400-cps synchronous clock motor is driven from an 800-cps transistorized crystal oscillator using a voltage-doubling chopper circuit and a 28-volts dc power supply.

531.76:621.373.43 2827

**The Measurement of Periodically Recurring Short Time Intervals**—R. Gerharz. (*Z. angew. Phys.*, vol. 9, pp. 282–286; June, 1957.) The use of pulse generators with high repetition frequency (see 2065 of 1957) for calibration purposes is discussed. By using two identical pulse generators to produce a beat frequency curve on a CRO screen, time interval measurement with a resolution of at least $100^{-11}$ seconds have been made.

621.317.31.024.42 2828

**Method of Measuring and Recording "Ultra Small" Currents**—L. L. Dekabrun. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1578–1583; July, 1957.) Electrometer tube circuits are described by means of which currents up to $10^{-14}$ amperes are measured. This is accomplished by passing the current through resistances of $10^{10}$–$10^{12}\Omega$ and by measuring the voltage drop. The instrument has a good stability and an accuracy within ±10 per cent.

621.317.32:621.396.822 2829

**Noise Voltage Measurements on Low-Impedance Circuit Elements by means of a Valve Amplifier with Input Transformer**—W. Nonnenmacher. (*Nachrtech. Z.*, vol. 10, pp. 559–563; November, 1957.) Equivalent noise impedance of less than 1Ω can be determined at low and medium frequencies by the method described. Additional noise due to the input transformer can be eliminated.

621.317.32.024:621.375.9:537.312.62 2830

**A Sensitive Superconducting "Chopper" Amplifier**—De Vroomen and Van Baarle. (See 2675.)

621.317.331 2831

**Measurement of Sheet Resistivities with the Four-Point Probe**—F. M. Smits. (*Bell Sys. Tech. J.*, vol. 37, pp. 711–718; May, 1958.) See also 1502 of 1954 (Valdes).

621.317.331.028.3 2832

**The Measurement of High Value Resistances**—J. K. Wood. (*Electronic Eng.*, vol. 30, pp. 374–377; June, 1958.) Several methods using standard laboratory equipment are described together with sources of error and ways of reducing them.

621.317.34:621.397.5 2833

**Measurement of the Reflection Coefficient of Television Lines and Equipment**—E. Thinius. (*Nachrtech. Z.*, vol. 10, pp. 548–550; November, 1957.) Using a frequency-sweep oscillator a response curve is obtained on a CRO screen, from which the reflection coefficient and phase angle can be determined.

621.317.361 2834

**Frequency Measurement by Time Delay of a Signal**—A. I. Danilenko. (*Radiotekhnika, Mosk.*, vol. 12, pp. 67–72; May, 1957.) Two voltages are applied to a summation device, one from the oscillators under investigation and the other from the same oscillator but delayed in time. The amplitude of the resulting voltage will depend on frequency. The method might be used to determine the characteristics of delay lines.

621.317.411:621.372.413:538.221:621.318.134 2835

**Frequency Shifts in Cavities with Longitudinally Magnetized Small Ferrite Disks**—Seidel and Boget. (See 2813.)

621.317.61:621.372.8:621.376.232 2836

**A Phase-Sensitive Detector**—Beauchamp. (See 2687.)

621.317.71:537.228.1 2837

**Simple Apparatus for the Direct Determination of the Charge Output of Piezoelectric Materials at High Forces**—D. S. Schwartz. (*Rev. Sci. Instrum.*, vol. 29, pp. 321–323; April, 1958.) Compressions varying from 50 to 15,000 pounds are obtained with hydraulic vices. The charge is measured using a Miller integrator circuit which presents a very low impedance to the sample.

621.317.733:621.372.412.209.62 2838

**Plug-in Bridge Checks V.H.F. Quartz Crystals**—D. W. Robertson. (*Electronics*, vol. 31, pp. 82–85; May 9, 1958.)

621.317.755:537.52 2839

**A Multiple-Beam Oscilloscope for the Study of High-Voltage Transient Discharges**—K. G. Beauchamp. (*Electronic Eng.*, vol. 30, pp. 358–365; June, 1958.) High-voltage transient discharge phenomena are studied by means of trace expansion and selective brightening. The effects of corona and main discharge can be separated in the instrument. The complete design is given.

621.317.755:537.52 2840

**The Synchronized Plasmograph**—R. Ledrus, M. Hoyaux, A. Vanavermaete, and P. Gans. (*Rev. gén. Élect.*, vol. 66, pp. 513–521; October, 1957.) Refinement of an instrument described earlier [532 of 1956 (Ledrus, *et al.*)].

621.317.763.089.6:621.372.414.029.63 2841

**Measuring Decimetric Wavelengths**—H. B. Dent. (*Wireless World*, vol. 64, pp. 319–323; July, 1958.) Lecher wires are used to calibrate an absorption wavemeter covering the range 450–750 mc.

621.317.799:[621.314.63+621.385.029.6 2842

**Diode and Klystron Test Set for the 3.2-cm Region**—W. Otto. (*Nachrtech.*, vol. 7, pp. 454–460; October, 1957, and pp. 502–506; November, 1957.) The equipment described is designed for production tests on Si diodes and reflex klystrons used as mixers and local oscillators, respectively.

621.317.799:621.385.1 2843

**High-Speed Tester Checks Tubes in Groups**—E. S. Gordon. (*Electronics*, vol. 31, pp. 76–78; May 9, 1958.)

## OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.7:681.142 2844

**The Synchro Resolver as a Shaft Position Transducer**—M. B. Wood. (*Electronic Eng.*, vol. 30, pp. 366–370; June, 1958.) The resolver is part of a phase-shifting unit with 400-cps sinusoidal input. The difference in time-phase of the output zero crossover in the reference and measuring channels is measured by a period counter. The relation between shaft and crossover pulse position is linear to within ±0.1 per cent.

551.508.7:621.316.825 2845

**Captive Balloon Refractovariometer**—A. L. Crozier. (*Rev. Sci. Instrum.*, vol. 29, pp. 276–279; April, 1958.) A system is described for measuring and recording rapid (3-cps) fluctuations of refractive index, humidity, and temperature using fast-response-thermistor beads. Measurements can be obtained up to 5000 feet above the measuring site.

621.383.4:612.84 2846

**Retinal Type of Photovoltaic Cell**—I. Levin. (*Nature, London*, vol. 181, p. 832; March 22, 1958.) A multielectrode photocell analogous to the retina and an amplifier unit analogous to the nervous system of the eye are described.

621.383.8:537.311.33:535.34.096 2847

**A New Thermal Image Converter**—W. R. Harding, C. Hilsum, and D. C. Northrop. (*Nature, London*, vol. 181, pp. 691–692; March 8, 1958.) A simple image converter can be made based on the temperature dependence of the absorption threshold in a semiconductor. In the example described a self-supporting film of Se is metallized on one side and mounted in a vacuum at the focus of a parabolic mirror. The film is viewed by transmitted light from a sodium lamp. Variations in temperature or emissivity in the scene focused on the semiconductor appear as differences in transmitted intensity.

621.384.6 2848

**Focusing of High-Velocity Electrons in Linear Electron Accelerators**—K. N. Stepanov and A. A. Sharshanov. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1863–1869; August, 1957.) The radial movement of high-velocity relativistic electrons is examined and equations are derived.

621.384.6 2849

**The Focusing of Beams of Charged Particles by High-Frequency Fields**—M. A. Miller. (*Doklady Akad. Nauk S.S.S.R.*, vol. 119, pp. 478–480; March 21, 1958.) Mathematical analysis applied to an example of the focusing of a rectilinear beam in the field of symmetry of a $\text{Te}_{10}$-mode wave propagated in a circular waveguide with ideally conducting walls.

621.384.6+621.385.029.6]:621.372.2 2850

**The Propagation of Slow Waves**—Dain. (See 2933.)

621.384.612 2851

**Resonance Perturbation of Synchrotron Oscillations in Particle Accelerators**—I. S. Danilkin and M. S. Rabinovich. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1558–1570; July, 1957.) The influence of the resonance harmonic disturbances on the phase shift and the intensity of the beam of accelerated particles is investigated. A synchrophasotron of 10 kmev is used.

621.384.613 2852

**Investigation of Electron Capture Processes in a Betatron**—Yu. S. Kofobochko. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1603–1605; July, 1957.) The average number of revolutions of an electron in a 15-mev betatron was estimated to be 4–5; the current circulating in the orbit during the trapping period was calculated and the trapping efficiency assessed.

621.384.7 2853

**Theory of an Electric High-Frequency Mass Spectrometer**—G. Falk, and F. Schwering. (*Z. angew. Phys.*, vol. 9, pp. 272–275; June, 1957.) A static and a high-frequency field are superimposed inside a cylindrical capacitor through which the ion beam travels, and an absorption-type spectrum is produced.

621.385:621.317.7 2854

**An Ion-Optical Bench for the Study of Four-Pole Magnetic Lenses and of Magnetic Deflectors for Particle Accelerators**—A. Septier. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1406–1409; October 21, 1957.) A purely electrostatic system operating with an electron beam or with ions of any mass is described. Aberrations in the magnetic system under test are detected using a fluorescent screen.

621.385.833 2855

**Measuring with the Electron**—L. Marton. (*J. Sci. Ind. Res.*, vol. 16A, pp. 429–439; October, 1957.) A reviewer of electron-optical techniques in microscopy, field mapping, and interferometry.

621.385.833 2856

**Addition to the Theory of Aberration of an Electron-Optical Focusing System with a Curvilinear Axis**—Yu. V. Vandakurov. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1850–1862; August, 1957.) From the trajectory of particles, equations are derived by means of which the second and third-order geometrical aberration and first and second-order chromatic aberration for arbitrary electric and magnetic fields are calculated. Formulas are also given for the dispersion of particles corresponding to their velocities and masses. Conditions are determined for which second-order geometrical aberration does not occur.

621.375.833 2857

**Experimental Investigation of Aperture Aberrations of a System of Two Four-Pole Magnetic Lenses**—A. Septier. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1905–1908; November, 1957.)

621.385.833 2858

**Contrast in the Electron-Microscope Image**—R. C. Valentine. (*Nature, London*, vol. 181, pp. 832–833; March 22, 1958.) Three methods of comparing contrast are discussed and evaluated numerically.

621.385.833 2859

**Simultaneous Evaporation of Platinum and Carbon for Possible Use in High-Resolution Shadow-Casting for the Electron Microscope**—D. E. Bradley. (*Nature, London*, vol. 181, pp. 875–877; March 29, 1958.)

621.387.422 2860

**The Discharge Process in Proportional Counter Tubes**—C. Keck. (*Z. angew. Phys.*, vol. 9, pp. 286–292; June, 1957.)

621.387.462 2861

**Semiconductor Device for $\gamma$-Ray Indication**—S. M. Ryvkin. A. P. Bogomazov, B. M. Konovalenko, and O. A. Matveev. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1601–1602; July, 1957.) Best results were obtained with CdS and CdSe specimens, the conductivity of which changes sharply when irradiated.

621.387.462:546.289 2862

**The Use at Low Temperature of $n$-$p$-Type Germanium $\alpha$-Particle Counters**—A. V. Aĭrapetyants, A. V. Kogan, N. M. Reĭnov, S. M. Ryvkin, and I. A. Sokolov. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1599–1600; July, 1957.)

621.398.621.391 2863

**Some Problems of Telemetry in the Light of Communication Theory**—V. Pollak. (*Hochfrequenztech. u. Elektroakust.*, vol. 66, pp. 19–25; July, 1957.) Communication theory is applied to the analysis of telemetry systems used in power transmission.

621.398:621.391 2864

**Systems Engineering a P.D.M./F.M. Telemetry System**—F. J. Enge. (*Electronic Ind.*, vol. 17, pp. 80–81, 128; March, 1958.) The basic principles involved in a PWM/FM telemetry system are discussed in relation to information theory.

## PROPAGATION OF WAVES

621.396.11:551.510.52 2865

**Tropospheric Scatter Propagation—a Summary of Recent Progress**—H. Staras. (*RCA Rev.*, vol. 19, pp. 3–18; March, 1958.) A short history and an explanation in terms of physical concepts are given. In discussing bandwidth capabilities, correlation distances, antenna-to-medium coupling loss, and angular diversity, published theoretical work is compared with recent experimental data.

621.396.11:551.510.52 2866

**The Effect of Refraction on the Scatter Propagation of Ultra Short Waves in the Troposphere**—D. M. Vysokovskiĭ. (*Radiotekhnika, Mosk.*, vol. 12, pp. 30–36; May, 1957.) Approximate formulas are derived for determining the effect of such factors as the lowering of the height of the scattering region, the variation of the angle of scattering, and the variation of the extent of the scattering region. The variation of power at the point of reception in the presence of refraction is calculated. The results obtained are compared with the theoretical and experimental data on the scattering of radio waves at turbulent inhomogeneities.

621.396.11:551.510.535 2867

**Observations on Back-Scatter Echoes in Long-Distance Short-Wave Transmissions**—H. U. Widdel. (*Arch. elekt. Übertragung*, vol. 11, pp. 429–439; November, 1957.) The influence of antenna radiation patterns on the range and complexity of back-scatter echo observations was investigated using 1-ms pulses transmitted at a rate of 50/sec at frequencies of 5980, 9640, 15,275, and 17,845 kc. Two rhombics and one 250-m long-wire antenna 8 km from the transmitter were used for reception.

621.396.11:551.510.535 2868

**The Role of Ionospheric-Layer Tilts in Long-Range High-Frequency Radio Propagation**—S. Stein. (*J. Geophys. Res.*, vol. 63, pp. 217–241; March, 1958.) The mechanism of reflection of HF radio waves from a nonspherical layer is studied by means of simplified models. Rays emitted from a ground transmitter at low angles of elevation and reflected from a suitably tilted *F* layer will miss the earth and illuminate a second area of the layer directly. If sufficient ionization exists in this second area, the ray will be propagated around the curve of the earth. A ray may be reflected several times and finally encounter a tilt so oriented that the surface of the earth is illuminated. Anticipated fading, MUF and field-strength characteristics for these "$^{n}F$" modes are discussed. Many different $^{n}F$, and combinations of $^{n}F$ and conventional modes have been observed by back-scatter sounding between 12 mc and 30 mc and they are described.

621.396.11.029.45:551.510.535 2869

**An Extension to the Mode Theory of V.L.F. Ionospheric Propagation**—J. R. Wait. (*J. Geophys. Res.*, vol. 63, pp. 125–135; March, 1958.) The waveguide mode theory of VLF propagation for a sharply-bounded homogeneous ionosphere is refined to include stratification at the lower edge of the ionosphere. The numerical results for a two-layer model are discussed in detail.

621.396.11.029.62 2870

**Further Results of Tropospheric Drift Observations on the Question of the Mechanism of Long-Range Propagation at Metre Wavelengths**—L. Klinker. (*Z. Met.*, vol. 11, pp. 339–344; October/November, 1957.) 130 of the 160 measurements of tropospheric drift made in the course of one year's observations at Kühlungsborn (see 3279 of 1957) were compared with simultaneous aerological measurements made at Copenhagen. An analysis of the results appears to confirm earlier conclusions (see 587 of 1958).

## RECEPTION

621.396.62:621.314.7:621.311.69 2871

**Radio Waves power Transistor Circuits**—L. R. Crump. (*Electronics*, vol. 31, pp. 63–65; May 9, 1958.) Unpowered transistorized receivers are actuated by switching on a transmitter. The outputs from the receiving antennas need to be about 1 mw.

621.396.62.029.63/.64:621.396.822 2872

**Noise Performance of a Three-Stage Microwave Receiver**—H. V. Shurmer. (*Electronic and Radio Engr.*, vol. 35, pp. 271–274; July, 1958.) The analysis of the noise performance of microwave receivers is extended to the case where a crystal tube is preceded by a stage of RF amplification, such as a traveling-wave tube.

621.396.621.54:621.476.33 2873

**Bandwidth, Number of Stages and Distortion Factor in V.H.F. F.M. Receivers**—E. G. Woschni. (*Nachrtech.*, vol. 7, pp. 441–447; October, 1957.) The interdependence of selectivity, distortion factor, number of IF stages, and bandwidth is investigated and curves showing these relations are given.

621.396.812.3 2874

**Distribution of the Duration of Fades in Radio Transmission: Gaussian Noise Model**—S. O. Rice. (*Bell Sys. Tech. J.*, vol. 37, pp. 581–635; May, 1958.) The fluctuations of a received radio signal due to fading are assumed to behave like the envelope of narrow-band Gaussian noise. Estimates of the distribution of the fade lengths for various depths of fades are given, and relations which may be useful in analyzing fading data are derived. A similar problem involving the separation of the intercepts of the noise current itself, instead of its envelope, is also discussed.

621.396.82 2875

**Experimental Investigation of the Limitation of Pulse Interference by Varying the Spectra and the Threshold of Limiting**—A. A. Gorbachev. (*Radiotekhnika, Mosk.*, vol. 12, pp. 64–68; June, 1957.) In this method the signal and interference spectra are transformed by two linear converters to make use of certain features of the spectra, and the threshold of the limiter is made to follow automatically the level of the signal. Experiments have shown that good suppression is obtained of pulses of duration up to several milliseconds.

## STATIONS AND COMMUNICATION SYSTEMS

621.376:621.395.665.1 2876

**Automatic Speech Amplitude Control**—L. R. Battersby. (*Electronics*, vol. 31, pp. 71–73; May 23, 1958.) A simple differentiating network changes the energy distribution of speech so that input amplitude variations of up to 35 db over the range 300–3000 cps are reduced to output variations of about 1 db without serious loss of intelligibility. Field tests with portable FM transceivers show that a marked increase in AF output can then be obtained when the RF signal/noise ratio is poor.

621.391 2877

**On the Relation between the Rate of Transmission of Information and the Freedom from Interference in a Communication System**—E. L. Blokh. (*Radiotekhnika, Mosk.*, vol. 12, pp. 3–14; June, 1957.) The relation is investigated with the aid of geometrical methods for codes corresponding to the simplest and the densest distributions of signal points.

621.391:621.396.82 2878

**Statistical Properties of Signals and Interference in Two-Channel Phase Systems**—V. V. Tsvetnov. (*Radiotekhnika, Mosk.*, vol. 12, pp. 12–29; May, 1957.) Statistical properties of sinusoidal signals and Gaussian interference in two-channel phase systems are discussed and the law of the distribution of amplitude and phase differences is derived. The statistical characteristics are considered for the following cases: a) instantaneous phase error and uncorrelated two-channel interference; b) relatively strong signals.

621.391:621.396.822 2879

**Zeros of Gaussian Noise**—G. M. White. (*J. Appl. Phys.*, vol. 29, pp. 722–729; April, 1958.) Results are reported of an investigation by an experimental technique for determining the statistics of the times a random function crosses through its average value. Close agreement was found with values calculated theoretically; others not amenable to calculation gave results intuitively expected. The equipment is briefly described.

621.396.712 2880

**The New Transmitting Station at Lourenço Marques in Mozambique**—M. Dick. (*Brown Boveri Rev.*, vol. 44, pp. 420–427; October, 1957.) The 3.2–22-mc transmitter described can also be used for transmitting at any frequency in the medium-wave band.

621.396.712:621.396.677.3 2881

**Long-Distance H.F. Broadcasting**—Bennington. (See 2637.)

## SUBSIDIARY APPARATUS

621.3.013.78 2882

**The Reflection and Screening Effects of Metallic Enclosures in a Plane Electromagnetic Wave**—H. Kaden. (*Arch. elekt. Übertragung*, vol. 11, pp. 403–415; October, 1957.) Three cases of reflection and screening action are investigated for wavelengths of the order of the dimensions of the enclosure: a) a hollow cylinder with axis parallel to the electric field, b) a hollow cylinder with axis parallel to the magnetic field, and c) a hollow sphere. The increase of the reflection coefficient with rising frequencies, screen attenuation, and resonance effects are discussed. See also 578 of 1957.

621.311.69:539.16 2883

**Nuclear Batteries**—E. K. Aschmoneit. (*Elektronik*, vol. 6, pp. 287–290; October, 1957.) Outline of principles of operation and applications. See also 1916 of 1957 (Milliron).

621.311.69:621.396.62:621.314.7 2884

**Radio Waves power Transistor Circuits**—Crump. (See 2871.)

621.314.63:537.311.33 2885

**Voltage/Current Characteristics of Semiconductor Power Rectifiers**—E. I. Rashba and A. I. Nosar'. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1431–1445; July, 1957.) The distribution of the concentration of carriers of *p-i-n* and *p-n-n* types is examined. Monomolecular and bimolecular recombinations are considered. The dependence of the injection coefficient on the current and the *V*/*I* characteristics are calculated and the voltage drop in the bulk of the semiconductor is investigated.

621.314.63:546.28 2886

**Medium-Power Silicon Rectifiers**—R. J. Andres and E. L. Steele. (*Electronic Ind.*, vol. 17, pp. 62–65; March, 1958.) The construction, manufacturing techniques, and electrical characteristics of the diode Type-MN-14 of *p-i-n* structure are described.

621.316.722.1:621.314.7 2887

**Stabilized Power Supplies using Transistors**—E. Baldinger and W. Czaja. (*Z. angew. Math. Phys.*, vol. 9, pp. 1–25; January 25, 1958.) The operation of simple stabilizing circuits is analyzed and methods of improvement by pre-amplification or compensation are discussed. Practical circuits which have low temperature coefficients are described.

## TELEVISION AND PHOTOTELEGRAPHY

621.397.5:535.623:061.3 2888

**International Symposium, Physical Problems of Colour Television, Paris, July 1957** (*J. Opt. Soc. Amer.*, vol. 48, pp. 73–74; January, 1958.) Proceedings on this conference are to be published by *Acta Electronica*, 23 rue du Retrait, Paris 20ᵉ.

621.397.61 2889

**Television Transmitters**—V. Milliquet. (*Brown Boveri Rev.*, vol. 44, pp. 438–446; October, 1957.) An installation comprising a 1.5-kw vision transmitter and a 300-watt FM sound transmitter is described.

621.397.611.2 2890

**Mechanism of Electronic Commutation in Television Tubes with Energy Storage**—Ya. A. Ryftin. (*Zh. Tekh. Fiz.*, vol. 27, pp. 1870–1885; August, 1957.) A comparison of experimental and theoretical results shows that the main characteristics of a storage-type camera tube can be improved by increasing the relative line shift. This can be achieved by increasing the size of the target or by decreasing the effective radius of the scanning spot. Results are presented graphically.

621.397.611.2 2891

**Some New Structure-Type Targets for the Vidicon—an Analysis of their Operation**—S. A. Ochs and P. K. Weimer. (*RCA Rev.*, vol. 19, pp. 49–61; March, 1958.) Two types of target are discussed, a) a "lateral-flow" structure with photocurrents flowing parallel to the target plane, and b) a "bridge-type" structure with each picture element providing an internal closed circuit thus establishing a charge pattern independently of the scanning beam. Experimental structure-type targets capable of several hundred lines resolution are described but are more difficult to make than conventional layer-type targets. Use can be made of sensitive photoconductors with resistivity too low for the standard vidicon.

621.397.62 2892

**Assessment of the Quality of Horizontal Synchronization in Television Receivers**—H. Lutz. (*Arch. Elekt. Übertragung*, vol. 11, pp. 461–470; November, 1957.) Parameters governing the operation of a phase-comparison system of horizontal synchronization are derived with reference to the operating point on the control-circuit characteristic. The noise characteristics of the system and its response to a sine-wave or pulse disturbance are calculated and a circuit for measuring these properties is described. A full evaluation of pull-in and locking properties is only possible if the nonlinear part of characteristic of the control circuit is known. Methods of plotting the unstable portion of the characteristic and of analyzing the pull-in process are described.

621.397.62:621.385.832 2893

**A Television Picture Tube with Increased Effective Perveance for Cathode Modulation**—W. F. Niklas, C. S. Szegho, and J. Wimpffen. (*J. Telev. Soc.*, vol. 8, pp. 368–375; January/March, 1958.) The tube characteristics associated with grid and cathode modulation are examined. The requirements for a new picture tube designed for cathode modulation are listed. Special features of the electron gun are described.

621.397.62:621.396.662 2894

**Performance of Television Turret Tuners**—K. H. Smith. (*J. Telev. Soc.*, vol. 8, pp. 337–390; January–March, 1958.) A detailed description of experimental work on circuits and tube design for improving Band-III noise performance and gain.

621.397.62:621.396.662 2895

**A Comparison of Turret-Type and Switch-Type Television Tuners**—V. A. Jones. (*J. Brit. IRE*, vol. 18, pp. 346–347; June, 1958. Discussion, pp. 349–357.) A table comparing the characteristics of German, U. S., and British tuners is given.

621.397.62:621.396.662.002.2 2896

**Mass-Production Techniques for Television Tuners**—P. C. Ganderton. (*J. Brit. IRE*, vol. 18, pp. 331–340; June, 1958. Discussion, pp. 349–357.) Design details for Band I, II, and III turret-type tuners, to ensure uniformity of performance and freedom from temperature effects. A system using "wobbulated" signals for coil alignment is described.

621.397.62:621.396.662.002.2 2897

**Some Aspects of Television Tuner Production**—S. H. Perry. (*J. Brit. IRE*, vol. 18, pp. 341–345; June, 1958. Discussion, pp. 349–357.) A statistical method for analyzing production variations in a particular type of tuner is described, together with manufacturing methods used to achieve the required accuracy and standardized performance.

621.397.62:621.396.665 2898

**A.G.C. Circuits in Television Receivers**—S. N. Doherty and P. L. Mothersole. (*J. Telev. Soc.*, vol. 8, pp. 350–367; January–March, 1958.) The problem of obtaining a wide range of AGC is discussed and a range of 80 db is shown to be possible. The development is described of a simple high-gain gate circuit which is free from the faults of existing circuits.

621.397.62:621.396.665 2899

**Automatic-Gain-Control Circuits in Television Receivers for Negative-Modulation Systems**—P L. Mothersole. (*J. Brit. IRE*, vol. 18, pp. 307–316; May, 1958.) A simple gate circuit is described in which the AGC potential is dependent on the black level of the signal and is completely independent of the line time-base frequency. The circuit also has the advantages of a) direct coupling, b) high input impedance, c) relatively few valves, and d) synchronizing pulse concellation.

## TRANSMISSION

621.396.61 2900

**Peculiar Features in the Design of Radio Transmitters in which the Anode Circuits are Fed from Sources with a High Internal Impedance**—N. I. Shteln. (*Radiotekhnika, Mosk.*, vol. 12, pp. 48–53; May, 1957.) The optimum utilization of dc sources with a relatively high internal impedance, such as rotary converters and thermionic rectifiers, is discussed. Recommendations are given for the design of tube oscillators to ensure the highest output.

621.396.61:621.396.822.1 2901

**Combination Frequencies and Crosstalk in Transmitters for Class-*C* Operation**—L. Leng. (*Brown Boveri Rev.*, vol. 44, pp. 433–437; October, 1957.) Theoretical investigation of the conditions under which crosstalk arises in stations where several transmitters are housed together.

621.396.71 2902

**New Brown Boveri Transmitters all over the World**—S. Pedersen. (*Brown Boveri Rev.*, vol. 44, pp. 400–409; October, 1957.)

621.396.712 2903

**Modern Regional Broadcast Transmitters**—W. Klein. (*Brown Boveri Rev.*, vol. 44, pp. 416–420; October, 1957.) Description of a 25-kw medium-wave transmitter.

621.396.712:621.376.3 2904

**Frequency-Modulated V.H.F. Broadcast Transmitters**—K. Lutz (*Brown Boveri Rev.*, vol. 44,, pp. 409–415; October, 1957.) Brief description of a new series of transmitters available for 1, 3, and 10 kw outputs.

## TUBES AND THERMIONICS

621.314.63 2905

**The Potential of Semiconductor Diodes in High-Frequency Communications**—A. Uhlir, Jr. (PROC. IRE, vol. 46, pp. 1099–1115; June, 1958.) The construction, properties, and applications of three types of diode are described. Graded *p-n* junctions made by solid-state diffusion are low-loss nonlinear capacitors which can be used for low-noise amplifiers, amplifying frequency converters, harmonic and subharmonic generators, switches, limiters, and voltage-tuned passive circuits. Point-contact diodes (or *p-n* junctions at lower frequencies) are nonlinear resistors, used as microwave rectifiers. *p-i-n* diodes have a high-frequency resistance which is dependent on the direct current, and so can be used as wide-band microwave switches or attenuators.

621.314.63 2906

**The Evolution of the Theory for the Voltage/Current Characteristic of *P-N* Junctions**—J. L. Moll. (PROC. IRE, vol. 46, pp. 1076–1082; June, 1958.) The rectifying action is controlled essentially by the equilibrium densities, diffusion constants, and recombination times of minority carriers. Low-level behavior of Ge junctions at room temperature is described theoretically on the basis of diffusion and recombination rates on either side of the barrier region. For Si, effects of carrier recombination and generation in the barrier region must be included. At high current densities, junctions depart from the ideal low-level rectifier law because of effects associated with majority-carrier modulation.

621.314.63:537.311.33 2907

**The Time-Lag of Semiconductor Diodes in Pulse Operation and its Physical Interpretation**—W. Heinlein. (*Arch. elekt. Übertragung*, vol. 11, pp. 387–396; October, 1957.) An interpretation of the delay mechanism operative in pulse-controlled *p-n* junctions is confirmed by measurements on Ge crystal diodes with large diffusion regions.

621.314.63+621.385.029.6]:621.317.799 2908

**Diode and Klystron Test Set for the 3.2-cm Region**—Otto. (See 2842.)

621.314.63+621.314.7].002.2 2909

**Outdiffusion as a Technique for the Production of Diodes and Transistors**—J. Halpern and R. H. Rediker. (PROC. IRE, vol. 46, pp. 1068–1076; June, 1958.) The diffusion of Sb out of Ge has been studied, and the use of this process shown to be an easy way of producing *p-n* junctions in compensated *n*-type Ge. High-speed narrow-base diodes and high-speed *n-p-n* Ge transistors have been made by outdiffusion.

621.314.7+621.314.63 2910

**Lumped Models of Transistors and Diodes**—J. G. Linvill. (PROC. IRE, vol. 46, pp. 1141–1152; June, 1958.) A lumped approximation is made at the beginning of analysis of a distributed system. This generally simplifies analysis, permits consideration of phenomena prohibitive to analysis on a differential basis, and provides a close tie with the physical aspects involved. Lumped models are shown which can be used to approximate the properties of transistors and diodes over a wide range of conditions and applications.

621.314.7 2911

**Transistors**—(PROC. IRE, vol. 46, pp. 952–1300; June, 1958.) This issue commemorates the tenth anniversary of the invention of the transistor. Abstracts of some of the papers are given individually; titles of others are as follows:—

1) **The Technological Impact of Transistors**—J. A. Morton and W. J. Pientenpol. (pp. 955–959.)
2) **Review of Other Semiconductor Devices**—S. J. Angello. (pp. 968–973.)
3) **Analogue Solution of Space-Charge Regions in Semiconductors**—L. J. Giacoletto. (pp. 1083–1085.)
4) **Germanium and Silicon Rectifiers**—H. W. Henkels. (pp. 1086–1098.)
5) **New Concepts in Microwave Mixer Diodes**—G. C. Messenger. (pp. 1116–1121.)
6) **Advances in the Understanding of the *P-N* Junction Triode**—R. L. Pritchard. (pp. 1130–1141.) Ninety-eight references.
7) **Construction and Electrical Properties of a Germanium Alloy-Diffused Transistor**—P. J. W. Jochems, O. W. Memelink, and L. J. Tummers. (pp. 1161–1165.)
8) **Technology of Micro-alloy Diffused Transistors**—G. G. Thornton and J. B. Angell. (pp. 1166–1176.)
9) **Power Transistors**—M. A. Clark. (pp. 1185–1204.)
10) **Measurement of Transistor Thermal Resistance**—B. Reich. (pp. 1204–1207.)
11) **Measurement of Internal Temperature Rise of Transistors**—J. T. Nelson and J. E. Iwersen. (pp. 1207–1208.)
12) **A Five-Watt Ten-Megacycle Transistor**—J. T. Nelson, J. W. Iwersen, and F. Keywell. (pp. 1209–1215.)
13) **The Effective Emitter Area of Power Transistors**—R. Emeis, A. Herlet, and E. Spenke. (pp. 1220–1229.)
14) **Multiterminal *P-N-P-N* Switches**—R. W. Aldrich and N. Holonyak, Jr. (pp.1236–1239.)
15) **The Application of Transistors to Computers**—R. A. Henle and J. L. Walsh. (pp. 1240–1254.)
16) **Application of Transistors in Communications Equipment**—D. D. Holmes. (pp. 1255–1260.)
17) **Transistor Monostable Multivibrators for Pulse Generation**—J. J. Suran. (pp. 1260–1271.)
18) **A Design Basis for Junction Transistor Oscillator Circuits**—D. F. Page. (pp. 1271–1280.)

**621.314.7** **2912**

**Two-Dimensional Current Flow in Junction Transistors at High Frequencies**—R. L. Pritchard. (Proc. IRE, vol. 46, pp. 1152–1160; June, 1958.) At HF the distributed nature of the base region must be taken into account. In the usual equivalent circuit, the ohmic base resistance must be replaced in general by a complex base impedance. The effect of this modification upon circuit performance is discussed and transistor design considerations are outlined.

**621.314.7** **2913**

**Junction Transistor Short-Circuit Current Gain and Phase Determination**—D. E. Thomas and J. L. Moll. (Proc. IRE, vol. 46, pp. 1177–1184; June, 1958.) Analysis is given showing that the complete common-base and common-emitter current-gain magnitude and phase characteristics as a function of frequency can be determined from three amplitude measurements, namely the low-frequency current gain, the magnitude of the common-emitter current gain at a single frequency in the common-emitter cutoff region and the common-base cutoff frequency. Equations are developed for determining the common-emitter and common-base short-circuit current gains from these three measurements.

**621.314.7** **2914**

**The Intrinsic-Barrier Transistor—How it Works**—J. M. Early. (*Bell Lab. Rec.*, vol. 36, pp. 86–90; March, 1958.) Examination of the structural limitations of a three-layer transistor leads to an estimate of the ultimate capabilities of alloy and grown-junction types and to the development of a new type of transistor triode, *p-n-i-p*, in which an "intrinsic" or neutral layer between the base and collector layers has permitted transistor operation at higher voltages and frequencies.

**621.314.7:621.314.63]:538.63** **2915**

**Transistors and Diodes in Strong Magnetic Fields**—H. A. Kampf. (*Electronic Ind.*, vol. 17, pp. 71–73; March, 1958.) The results of tests at field strengths up to 10 kg show that semiconductor devices give a more reliable performance in a magnetic-field environment than thermionic tubes.

**621.314.7:546.28** **2916**

**The Blocking Capability of Alloyed Silicon Power Transistors**—R. Emeis and A. Herlet. (Proc. IRE, vol. 46, pp. 1216–1220; June, 1958.) Experimental results on a series of Si *n-p-n* alloyed transistors show good agreement with theory. Details of the *I/V* characteristic are discussed. Three base resistivity regions are distinguished: a) pure breakdown, b) approximately simultaneous occurrence of breakdown and punch-through, and c) pure punch-through.

**621.314.7:546.28:621.318.57** **2917**

**The Electrical Characteristics of Silicon *P-N-P-N* Triodes**—I. M. Mackintosh. (Proc. IRE, vol. 46, pp. 1229–1235; June, 1958.) The *p-n-p-n* triode shows switching properties analogous to the conventional thyratron. A general analysis of four-region structures is given and applied specifically to the *p-n-p-n* triode. Much of the detailed behavior of the device can be explained in terms of this analysis and theoretical curves are given which are in good agreement with experimental results.

**621.314.7:546.289** **2918**

**Large-Area Germanium Power Transistors**—B. N. Slade and J. Printon. (*RCA Rev.*, vol. 19, pp. 98–108; March, 1958.) Both *p-n-p* and *n-p-n* experimental alloy-junction power transistors have been developed to operate at collector currents of 10 amperes by increasing the junction area and using ring-type emitters. Collector-to-base current ratios range up to 20 at 1 ampere and to 60 at 10 amperes. Thermal resistances are about 1–2°C/w.

**621.314.7:546.289** **2919**

**A High-Frequency Germanium Drift Transistor by Post-Alloy Diffusion**—J. S. Lamming. (*J. Electronics Control*, vol. 4, pp. 227–236; March, 1958.) Two or more impurities of different conductivity type are alloyed into *n*-type Ge to produce an alloyed *p-n* junction which is then modified by diffusion to produce a diffused *p-n* junction, the graded *n*-type region being suitable for the base and the *p*-type region for the emitter of a drift transistor. Alpha cut-off frequencies in excess of 200 mc with collector capacitances of 1.5 pf and base resistances of 50Ω have been achieved by this method.

**621.314.7:621.372.57** **2920**

**The Advantage of Considering a Transistor as an Active Quadripole**—A. Pinciroli and S. Fubini. (*Ricerca Sci.*, vol. 28, pp. 152–159; January, 1958.) The matrix analysis of tube networks used in 2744 of 1949 (Pinciroli and Taraboletti) is similarly applied to transistor circuits, which simplifies the solution of network problems.

**621.314.7:621.396.822** **2921**

**Noise in Junction Transistors**—A. van der Ziel. (Proc. IRE, vol. 46, pp. 1019–1038; June, 1958.) A survey of shot noise and flicker noise in junction diodes and transistors. The shot effect theory is treated in detail, both from the collective and corpuscular points of view. Fonger's theory of flicker noise is given. Experimental noise measurements are reviewed in relation to the theories described. Sixty-one references.

**621.314.7:681.142** **2922**

**Silicon-Germanium Transistors**—J. J. Bowe. (*Electronic Equipment*, vol. 5, pp. 26–27; September, 1957.) Temperature characteristics of point-contact transistors for computer applications are considered. Si-Ge alloy is shown by tests to be preferable to pure Ge.

**621.314.8.004.15** **2923**

**Evaluation of Transistor Life Data**—J. D. Johnson and B. VanSwearingen. (IRE Trans. on Reliability and Quality Control, no. PGRQC-11, pp. 15–26; August, 1957. Abstract, Proc. IRE, vol. 45, p. 1432; October, 1957.)

**621.383.27** **2924**

**Temperature Dependence of Photomultiplier Gain**—F. E. Kinard. (*Nucleonics*, vol. 15, pp. 92–97; April, 1957.) The gain stability of photomultipliers in the range −20° to +60°C was measured by recording output pulse height as a function of temperature when a light pulse of constant amplitude was applied.

**621.383.27** **2925**

**A Photomultiplier with Controllable Cathode Area**—W. Hartmann. (*Ann. Physik., Leipzig*, vol. 20, pp. 247–249; July 15, 1957.) An improvement in signal/noise ratio can be achieved by reducing the effective area of the photocathode by means of a control electrode to the minimum necessary for a given application.

**621.383.4:546.289** **2926**

**Narrow-Base Germanium Photodiodes**—D. E. Sawyer and R. H. Rediker. (Proc. IRE, vol. 46, pp. 1122–1130; June, 1958.) The operation of Ge photodiodes at room temperature both as reverse-biased and photovoltaic detectors is analyzed. General expressions are derived for the steady-state and the time-varying detector signal components. Equivalent circuits for both reverse-biased and photovoltaic operation are obtained as well as the noise equivalent circuit for reverse-bias operation. Advantages of a reduction in base width, and narrow-base photodiode design are discussed.

**621.383.4:546.48.231:535.371.07** **2927**

**A Hysteresis Effect in Cadmium Selenide and its Use in a Solid-State Image Storage Device**—F. H. Nicoll. (*RCA Rev.*, vol. 19, pp. 77–85; March, 1958.)

**621.383.4:546.48.241** **2928**

**Cadmium Telluride Photovoltaic Cells**—G. A. Lomakina, Yu. A. Vodakov, G. P. Naumov, and Yu. P. Naslakovets. (*Zh. Tekh. Fiz.*, vol. 27, p. 1594; July, 1957.) Samples having a specific conductivity of approximately $40\Omega^{-1}\cdot \mathrm{cm}^{-1}$ and a thermo-EMF of 200 μv/deg were investigated. When exposed to sunlight, these photocells gave an EMF>500 mv with an efficiency of 2 per cent.

**621.384.4:621.397.611.2** **2929**

**Differential Method of Lag Compensation in Photoconductive Devices**—H. Borkan and P. K. Weimer. (*RCA Rev.*, vol. 19, pp. 62–76; March, 1958.) By taking the difference of the signals from two photoconductive elements having unlike transient responses, a resultant signal can be obtained having a faster response than either element alone. Measurement of lag compensation using a pair of commercial photocells and a pair of photoconductive camera tubes have been made. The application of the method to a single camera tube, designed to yield a lag-corrected signal directly, is discussed.

621.385.029.6 2930

**Calculation of Resonance Frequencies of a Smooth-Anode Cylindrical Magnetron in the Brillouin State**—J. Coste. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1404–1406; October 21, 1957.) The perturbation method applied earlier [1903 of 1956 (Coste and Delcroix)] is outlined, and results of calculation are considered with reference to the analysis of Harris (3293 of 1952). Restriction of the Brillouin state to a distance from the cathode of twice the cathode radius, and an alteration of sign in a formula of Harris, lead to real values for the resonance frequencies.

621.385.029.6 2931

**An Electrostatically Focused Travelling-Wave-Tube Amplifier**—K. K. N. Chang. (*RCA Rev.*, vol. 19, pp. 86–97; March, 1958.) The principle of biperiodic focusing (640 of 1958) has been applied by using a pair of concentric bifilar helices and an annular gun. Design curves for choice of optimum geometry of the tube for a given beam perveance using a minimum focusing field are given. Experimental dc tests have shown a current transmission of 97 per cent with a beam perveance of about $2\times10^{-6}A/V^{3/2}$. A 10 db gain has been observed at 2970 mc.

621.385.029.6:537.533 2932

**Note on a Method of Investigation by Analogy of Interaction in Valves with Crossed Electric and Magnetic Fields**—D. Epsztein. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1790–1793; November 18, 1957.) The interaction between HF waves and an electron beam in crossed-field tubes is investigated by means of a CR tube in which analogous effects occur. See also 3703 of 1957.

621.385.029.6+621.384.6]:621.372.2 2933

**The Propagation of Slow Waves**—J. Dain. (*Electronic Eng.*, vol. 30, pp. 388–393; June, 1958.) A brief history of the use of continuous interaction between electrons and a traveling wave is given. The basic properties of the field patterns of traveling electromagnetic waves as applied to particle accelerators and microwave tubes are discussed and the techniques for measuring the main parameters are outlined. Consideration is given to simple and multiple periodic structures with particular reference to cross-wound helices and corrugated waveguides.

621.385.029.63:537.533:621.375.9 2934

**Parametric Amplification of the Fast Electron Wave**—R. Adler. (Proc. IRE, vol. 46, pp. 1300–1301; June, 1958.) A proposal for applying parametric amplification to the electron coupler described by Cuccia (2975 of 1949), by feeding a pumping signal to an electrode system so as to produce an inhomogeneous transverse field across the electron stream.

621.385.1 2935

**The Schottky-Langmuir Law of Discharges in a New Reference System for Small Electrode Distances**—K. Mie. (*Hochfrequenztech. u. Elektroakust.*, vol. 66, pp. 1–11; July, 1957.) A new approximation to the Langmuir solution is derived which is applicable to tubes with small electrode distances, operating under conditions very close to the Boltzmann limit.

621.385.1 2936

**Considerations Affecting the Rise and Decay of Cathode Currents in Receiving Tubes**—E. R. Schrader. (*RCA Rev.*, vol. 19, pp. 109–127; March, 1958.) Curves, resulting from the application or removal of heater, are analyzed to determine their dependence on various tube properties. Current decay is more reproducible and permits better resolution. In some types of tube changes in cathode activation appear as shifts of the temperature-limited region and sometimes as transient changes in the space-charge-limited region. Experiments with a diode having a rotating anode are used to illustrate the effects of cathode poisoning and reactivation.

621.385.1:621.317.799 2937

**High-Speed Tester Checks Tubes in Groups**—Gordon. (See 2843.)

621.385.3/.5+621.314.7]:621.396.822 2938

**Experimental Investigation of Low-Frequency Noise in Valves and Transistors**—V. B. Abramov and V. I. Tikhonov. (*Radiotekhnika, Mosk.*, vol. 12, pp. 45–51; June, 1957.) Measurements of the spectral intensity of noise are described and tables are compiled showing results obtained for various operating conditions.

621.385.5:621.396.822 2939

**The Noise Characteristics of the Valve Type EF 80 in the Low-Frequency Region**—M. Jansen and H. Lembke. (*Nachrtech.*, vol. 7, pp. 519–523; November, 1957.) Report on tests made on triode-connected tubes to obtain the noise spectrum in the range $1-10^7$ cps.

621.387 2940

**Lateral-Current Control Mechanism for Cold-Cathode Gas Discharges**—D. J. Belknap and L. R. Crump. (*J. Appl. Phys.*, vol. 29, pp. 737–738; April, 1958.)

621.387:621.316.722 2941

**Noise and Impedance Measurements in Voltage-Regulator Tubes**—A. van der Ziel and E. R. Chenetk. (*Physica*, vol. 23, pp. 943–952; October, 1957.) Results of a series of measurements over a frequency range 1 cps–30 mc indicate that at low frequencies both admittance and noise are influenced by the same current multiplication process.

## MISCELLANEOUS

621.3.004.15 2942

**On the Measurement of Component Reliability**—I. K. Munson. (IRE Trans. on Reliability and Quality Control, no. PGRQC-11, pp. 27–33; August, 1957.) In reliability tests at elevated temperature care must be exercised to ensure that the rise in temperature does not cure and hence conceal a defect in the component, *e.g.*, by annealing soldered parts.

413.164:[621.38+621.372.8 2943

**Elsevier's Dictionary of Electronics and Waveguides in Six Languages [Book Review]**—W.E. Clason. Elsevier, Amsterdam, and Clever-Hume Press, London, 628 pp.; 1957. (*Nature, London*, vol. 181, p. 801; March 22, 1958.) The languages included are English, French, Spanish, Italian, Dutch, and German.

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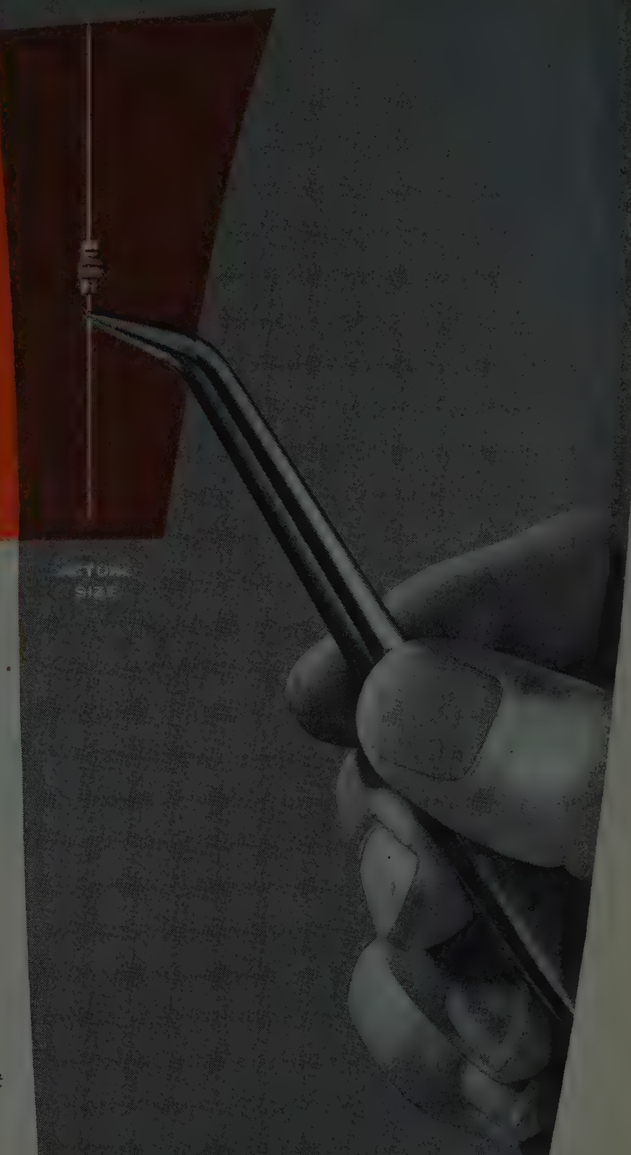

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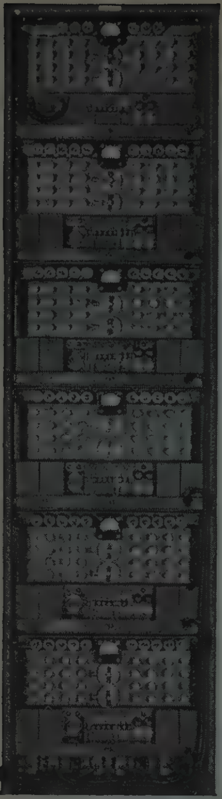

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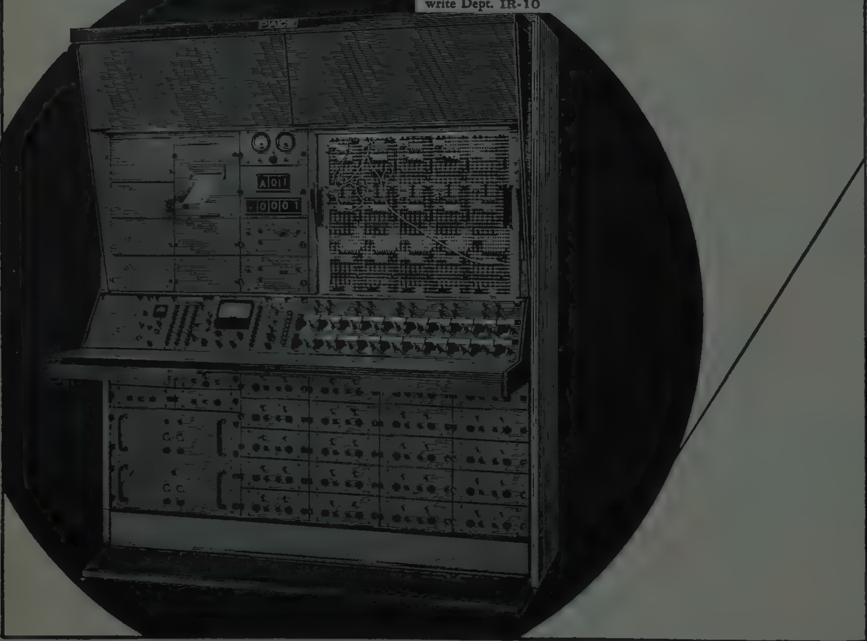

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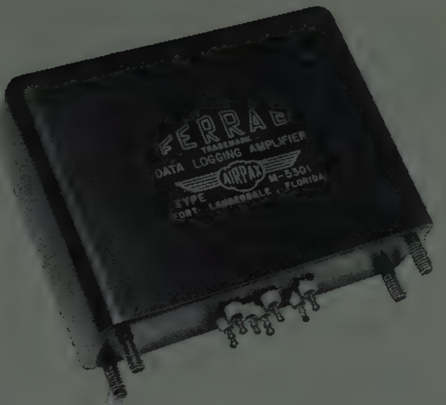
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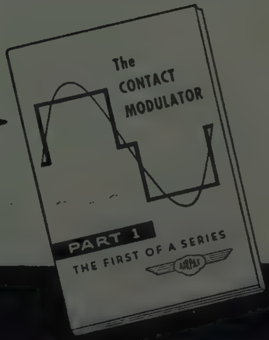
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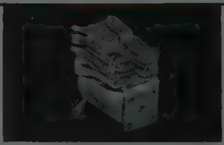

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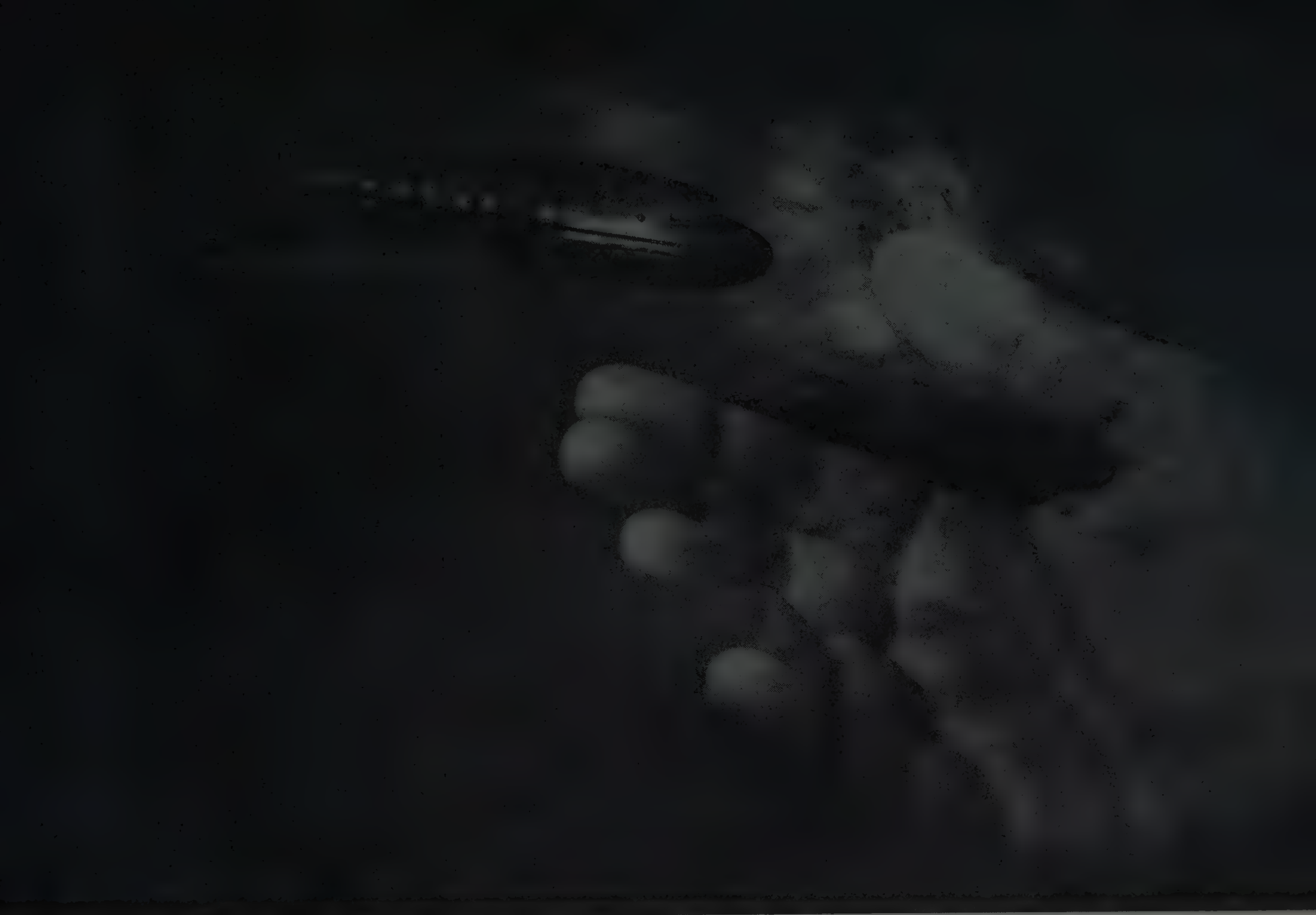

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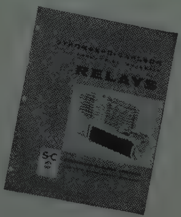

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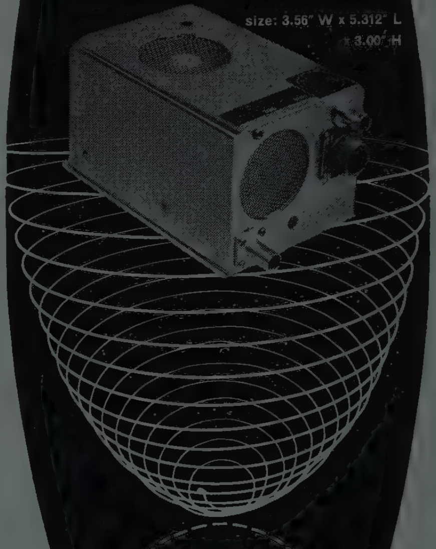
(Continued on page 108A)

INCREASED SIGNAL POWER



*in the 215 mc to 260 mc telemetering band*

**The Model REL-10** R-F Power Amplifier is a high-output unit for airborne applications. With power outputs from 10 to 100 watts, it dramatically increases the range of missile and aircraft telemetering systems...teams up with presently available FM transmitters...meets missile environmental requirements.

*For full specs, write for Data File IRE-500-2*

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DELCO HIGH POWER TRANSISTORS

Thousands of Delco high power germanium transistors are produced daily as engineers find new applications for them. In switching, regulation, or power supplies—in almost any circuit that requires high power—Delco transistors are adding new meaning to compactness, long life and reliability.

All Delco transistors are 13-ampere types and, as a family, they offer a collector voltage range from 40 to 100 volts. Each is characterized by uniformly low saturation resistance and high gain at high current levels. Normalizing insures their fine performance and uniformity regardless of age. Also important—all Delco transistors are in volume production and readily available at moderate cost.

For complete data contact us at Kokomo, Indiana or at one of our conveniently located offices in Newark, New Jersey or Santa Monica, California. Engineering and application assistance is yours for the asking.

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**Division of General Motors**
**Kokomo, Indiana**

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TRUE RMS RESPONDING
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AC-DC
RADIO FREQUENCY
VOLTMETERS

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VTVM
OSCILLATOR
MODEL RFV

**TRUE RMS RESPONDING RADIO FREQUENCY VOLTMETERS.** Direct-reading, thermocouple-type voltmeters particularly suitable for the accurate calibration of oscillators, signal generators, vacuum tube voltmeters and similar apparatus. The model RFV may also be used as an AC-DC transfer standard where maximum accuracy at high frequency is desired. Multi-range instruments from 1 v. to 300 v. full scale. Accuracy .5% on DC and from 7 cps to 5 megacycles on 1 v. range and to 150 kilocycles on 300 v. range. Higher frequencies at reduced accuracy. Formica cases available. DIAMOND PIVOTS and shock-mounted jewels of course!

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(Continued from page 106A)

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## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 52A)

### Jumbo Nixie Indicator

**Burroughs Corp., Electronic Tube Div.,** Plainfield, N. J., has announced a new addition to its line of Nixie indicator tubes called the Jumbo Nixie—type BD-307. This three inch diameter, all electronic in-line indicator is designed to meet the needs of visual presentation at viewing distances of over 150 feet. Low power and rugged construction are additional features according to the manufacturer.

The new Jumbo Nixie contains the numerals (0) through (9) and a common anode for circuit simplicity. The desired numeral is illuminated with a neon glow by applying a voltage (potential) between it and the common anode. Brightness and clarity as well as size of presentation make long distance viewing possible.

Further information can be obtained by contacting the firm direct.

(Continued on page 110A)

PLAN TO ATTEND

# NEREM

northeast electronics research and engineering meeting

wednesday and thursday, november 19-20

mechanics' bldg., boston

## THE PROGRAM

*Wednesday Morning*

### COMPUTERS I

"On the Transient Performance of Transistor-Resistor Logic Circuits"
"Inductively Controlled Computer Circuits"
"Transmission of Binary Data Over Telephone Lines"
"The Dynistor Diode — A New Computer Device"

### COMPONENTS

"New Developments in Glass Components"
"A New Slide Wire with Almost Infinite Resolution"
"Properties of Flat Conductor Cables"
"Stepped-Index Luneberg and Eaton Lenses"

*Wednesday Afternoon*

### TECHNIQUES

"Evaporative Cooling for Electronic Equipment"
"Electronic Flash High-Speed Photography"
"Measurement of Transient Response in R.F. Circuits"
"A Differential Meter of High Precision"

### CIRCUITS I

"Frequency Multiplication with Phase-Locked Oscillators"
"Effects of the Filter in Oscillator Synchronization"
"A Mechanical Method to Improve Bridge Balance Convergence"
"A New Method of Providing Selective Calling and Noise-Immune Squelch for Radio Links"

### RELIABILITY AND TESTING

"Reliability and Life Testing of Semiconductors"
"Potentiometer Test Station Performs Basic Tests with Single Mounting"
"Reliability Insurance for Electronic Equipment"
"Vacuum Tube Flip-Flop Design for Commercial Instrumentation"

*Wednesday Evening*

### INVENTIONS AND PATENTS

"From the Inventor's Point of View"
"From the Commercial Point of View"
"From the Legal Point of View"

*Thursday Morning*

### ELECTRON DEVICES

"Recent Advances in Very Fast Bonded Diodes"
"A UHF Metal-Ceramic Planar Tetrode"
"Characteristics and Applications of the Silicon Unijunction Transistor"
"A Filamentary Subminiature Triode for 500 Mc Application"

### TECHNICAL INFORMATION

"Technical Libraries in the Boston Area"
"Publications as Tools of the Electronics Industry"
" 'Do-It-Yourself' Technical Publications"
"Don't Lose What You Read"

### INFORMATION THEORY

"Capacity of a Certain Asymmetrical Binary Channel with Finite Memory"
"Signal-to-Noise Ratio Improvement Obtainable Through Digital Encoding of a Memoryless Binary Symmetric Channel"
" 'Matrix' Error Correcting Codes"
"On a Class of Error-Correcting Codes"

*Thursday Afternoon*

### COMPUTERS II

"A Method for Fast Non-Parallel Arithmetic in a Digital Computer: Parallel-Serial-Parallel"
"Arithmetic Operations for Digital Computers Using a Reflected Binary Code"
"Synthesis of Waveforms Derived From Printed Characters"
"Optical Data-Processing with Thin Magnetic Films"

### CIRCUITS II

"Audio Amplifier with Reduced Plate Dissipation"
"Chopper Stabilized Transistor Amplifier"
"Differential Amplifiers"
"New Developments in Distributed Amplifiers"

### REGISTRATION

*IRE Members FREE — non members $1.00*

### OVER 200 EXHIBITS

### COCKTAIL PARTY

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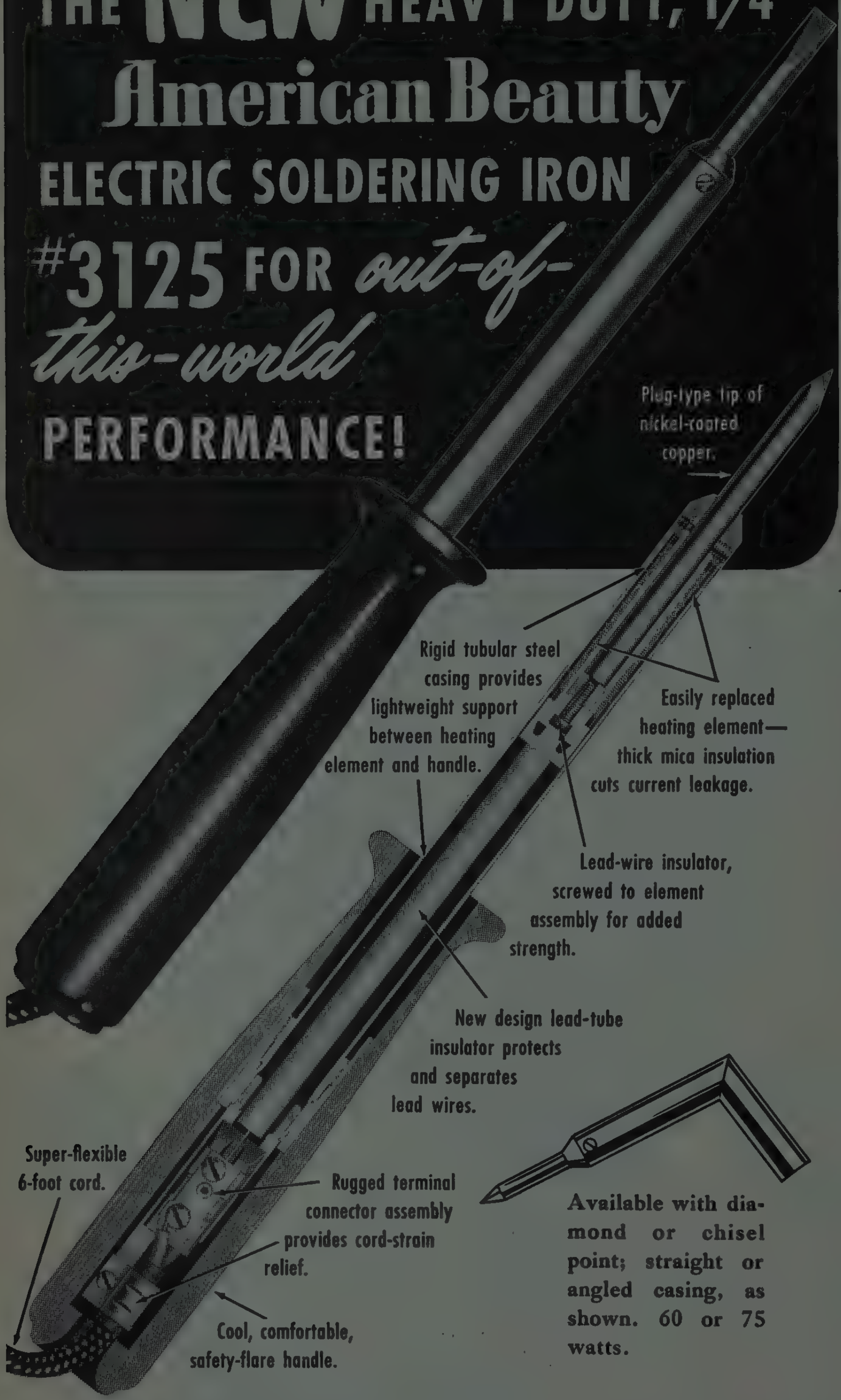
THE NEW HEAVY DUTY, 1/4"
American Beauty
ELECTRIC SOLDERING IRON
#3125 FOR *out-of-this-world* PERFORMANCE!


Plug-type tip of nickel-coated copper.
Rigid tubular steel casing provides lightweight support between heating element and handle.
Easily replaced heating element—thick mica insulation cuts current leakage.
Lead-wire insulator, screwed to element assembly for added strength.
New design lead-tube insulator protects and separates lead wires.
Super-flexible 6-foot cord.
Rugged terminal connector assembly provides cord-strain relief.
Cool, comfortable, safety-flare handle.

**Available with diamond or chisel point; straight or angled casing, as shown. 60 or 75 watts.**

American Beauty soldering irons have led the field in quality and production performance since 1894. There is a model to meet every soldering requirement.

Write for our 16 page catalog, showing our complete line, their use and care.

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American Beauty ELECTRIC IRONS SINCE 1894
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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 108A)*

## Multiple Preset Counter

Development of the new 2020 Multiple Preset Counters for counting and control applications has been announced by **Freed Transformer Co., Inc.,** 1720 Weirfield St., Brooklyn 27, New York. These counters can be supplied with multiple groups of presetting controls for use in all vital industrial operations for accurate, high speed sequential predetermining counting and control.

With these counters a complete program can be preset for winding multiple tapped coils or for any event which requires a machine controlled at different predetermined counts.

The new Freed 2020 Multiple Preset Counters can be supplied with various inputs, including photocell, mechanical contacts or pulses and operated at counting speeds up to 30,000 per minute. Dimensions for Type 2020-4-6 Preset Counters, illustrated, are: 13 inches, 11 inches wide by 8½ inches deep. Complete unit weighs 9 lbs.

For further information about the new 2020 Multiple Preset Counters and Freed's new Catalog No. 581 write directly to manufacturer, Freed Transformer Co., Inc.

## Transistorized Decimal Reversible Indicating Counter

**Di-An Controls, Inc.,** 40 Leon St., Boston 15, Mass., a new corporation staffed by the former employees of Mack Electronics research laboratory, announces availability of the transistorized Model 100-R Decimal Counter and Model DSR Decimal Storage Register.

The counter operates at pulse rates from zero to greater than 100,000 per second and can count either forward or

*(Continued on page 112A)*

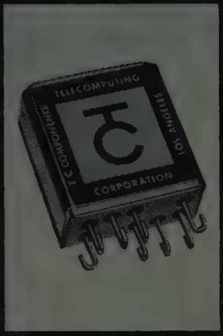
# Specify Reliable Components from Telecomputing

**HIGH TEMPERATURE CERAMIC CAPACITORS**

Featuring new ceramic dielectric and high capacity per unit area, TC Capacitors are designed for high temperature use, and subminiaturized for printed circuit mounting. Operating temperature −55°C to +150°C; Maximum capacity variation over entire temperature range ±10%; Voltage rating 200 WVDC; Proven Reliability; Conform to tentative MIL-C-11015B; Capacitance range 10mmf to .068mf.

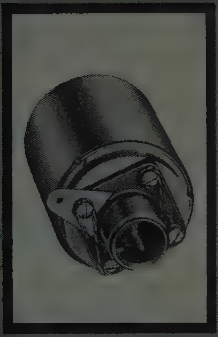
**SUMMIT ELECTRONIC PRODUCTS**

**Magnetic amplifiers, Precision ratio transformers, and Inductors** are custom designed to your requirements, or manufactured to your specifications. Summit products offer: precision, uniformity, rugged reliability, minimum lead time, test facilities to assure premium quality, packaging to your specification—encapsulated, potted, or taped for potting with your assemblies.



**MICRO MINIATURE RELAYS**

Designed for space and weight savings, hermetically sealed TC Relays conform to MIL R5757C and MIL R25018. Ambient temperatures −65°C to +125°C; standard units designed for 15 G's, special relays to 45 G's at 5 to 2000 cycles per second; coil resistance 30 to 10,000 ohms. Guaranteed life at 2 amp load, 100,000 cycles; at 5 amps, 12,000 cycles. Tests at 125°C ambient have produced 2 million operations at 2 amps, 60,000 at 5 amps.



**ROCKER SOLENOIDS**

For aircraft and missile applications, Rocker Solenoids are custom designed to all applicable specifications. Available movements: **push, pull, push-pull, switching, locking,** and **latching;** configurations: **miniature, pressurized,** and **hermetically sealed.** Low or high temperatures (to 800°F); continuous or intermittent operation; motions from thousandths of an inch to +1 inch; forces from 1 ounce to +100 pounds. Newly designed units act in less than 15 milliseconds.

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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 110A)

AM STANDARD
SIGNAL GENERATOR

*Type* **MS111**

10 kc/s to 110 Mc/s
on fundamentals

**AM:**
0—100%

**DISTORTION:**
0.5% at 30% AM
1.5% at 80% AM
5% at 90% AM

**OUTPUT VOLTAGE:**
0.2 μV to 0.2 V open circuit
0-2 V from separate jack

**OUTPUT IMPEDANCE:**
10 and 75 ohms
(10 and 50 ohms on request)

Incidental FM below 30 parts per million at 30% AM • Constant output on all ranges to 20 Mc/s • Electronically stabilized power supply • Extremely wide frequency range and low distortion AM make the instrument invaluable for lab. work.

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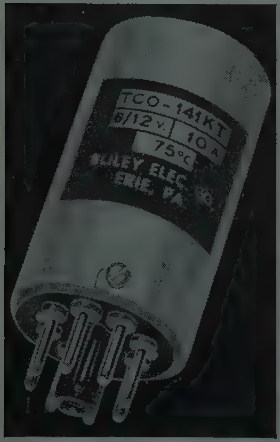
NEW CRYSTAL and COMPONENTS OVENS WITH SNAP-ACTION CONTROL



TCO-141 OVEN SERIES

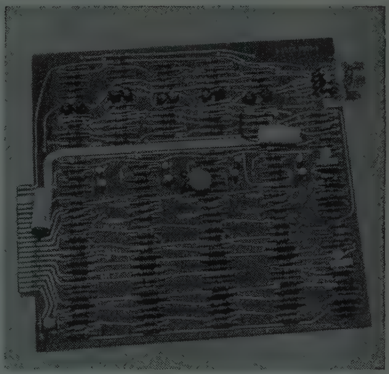
FOR HIGH RELIABILITY AND MINIMUM INTERFERENCE WITH LOW LEVEL CIRCUITRY . . .

Bliley TCO-141 Oven Series provide high reliability performance combined with snap-action thermostat feature for temperature control of crystals, transistors, diodes and other miniature electronic equipment. Dual heater windings permit 6 or 12 volt operation. Request Bulletin 515.

Bliley

BLILEY ELECTRIC CO. UNION STATION BUILDING
ERIE, PENNSYLVANIA

backward under command of a dc control voltage. The number in the counter is available in binary-coded decimal form as complementary dc output voltages of 0 and −6 volts, and is also displayed visually as an illuminated number on a "Nixie" indicator. A "carry" output for every ten input pulses is available for input to another decimal unit. The counter can be reset to zero by a pulse or contact closure on a "Reset" bus.



The counter has transfer gates to copy the state of the counter into a Model DSR decimal storage register upon application of a pulse to a "Transfer" bus. This transfer can be made either while the counter is counting forward or backward, or while it is not counting, and does not interfere with the counting function. The storage register will store the number until cleared to zero by a pulse on a "Clear" bus.

The counter is also available with any lesser combination of the special features enumerated if these functions are not all needed in a particular application.

The decimal counters and registers are both packaged on ten-inch-square printed-circuit plug-in boards. Mounting racks are available to accept the plug-in boards. Other packaging styles and sizes can be supplied to meet customer requirements.

## Tantalum Slug Capacitors Bulletin

Bulletin 150 discusses the advantageous characteristics of Series TS, tantalum slug capacitors, a new product from **Ohmite Manufacturing Co.,** 3694 Howard St., Skokie, Ill. Discussed are such features as the stability, shelf and operation life of these units, their greater capacitance per unit volume, and other characteristics. Applications and limitations of these polar-type units are covered; detailed physical and operating specifications are provided, along with a table of standard capacitance and voltage values.

For a free copy of this bulletin, write to Ohmite.

(Continued on page 114A)

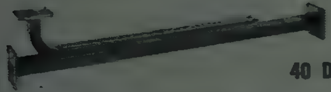
## DUAL HIGH DIRECTIVITY COUPLERS

Narda Dual High Directivity Directional Couplers are designed for reflectometer measurements in waveguide systems, and exhibit the same flat response (± 0.4) and high directivity (40 db min.) as Narda's single units. Primary line VSWR: 1.05 max. (1.10 for M1027); secondary line VSWR: 1.15 max.

Coupling structures are on opposite broad walls of the primary line; secondary output arms are on the same side. Detector mounts can be attached readily to facilitate connecting detector mounts.

| BAND | FREQUENCY (kmc) | WAVEGUIDE O.D. (in.) | NARDA Model | PRICE |
|---|---|---|---|---|
| S | 2.60-3.95 | 3 x 1½ | 1034 | $650. |
| C | 3.95-5.85 | 2 x 1 | 1033 | 400. |
| XN | 5.40-8.20 | 1½ x ¾ | 1032 | 255. |
| XB | 7.05-10.0 | 1¼ x ⅝ | 1031 | 220. |
| X | 8.20-12.4 | 1 x ½ | 1030 | 175. |
| KU | 12.4-18.0 | .702 x .391 | 1029 | 180. |
| K | 18.0-26.5 | ½ x ¼ | 1028 | 295. |
| V | 26.5-40.0 | .360 x .220 | 1027 | 330. |
| M | 50.0-75.0 | .226 x .154 | M1027 | 900. |

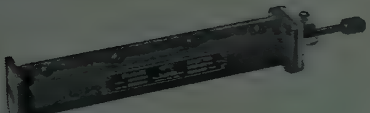
3, 6, 10 and 20 DB



40 DB HIGH POWER

## HIGH DIRECTIVITY COUPLERS

The 40 db High Power Coupler is another exclusive Narda product. Similar to standard types, except that coupling irises are in the narrow wall, it may be used at full rated power of the waveguide size. Nominal coupling value is 40 db; directivity 40 db. Directivity for 3, 6, 10 and 20 db couplers is also 40 db. Standard cover flanges on primary line; low VSWR termination and standard cover flange on secondary. All bands—2600 to 90,000 mc.



## STANDARD REFLECTIONS

Narda offers five values of reflections for each of six different waveguide sizes.. the most complete choice we know of! Provides calibrated reflections or VSWR's for use in standardizing reflectometers or calibrating slotted line impedance meters.

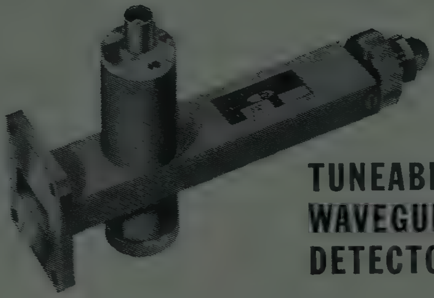
SPECIFICATIONS

| Reflection Coefficient | 0.00 | 0.05 | 0.10 | 0.15 | 0.20 |
|---|---|---|---|---|---|
| Accuracy | 0.002 | 0.0025 | 0.0035 | 0.0045 | 0.007 |
| VSWR Equivalent | 1.00 | 1.105 | 1.222 | 1.353 | 1.50 |

Models for 2.60 to 18.0 kmc, from $125 to $300

*Microwave engineers–*

# Where can you use these exclusive features offered by NARDA?



## TUNEABLE WAVEGUIDE DETECTORS

Narda's tuneable waveguide detectors are designed for broadband operation with small reflections and maximum versatility. Detected output is from a standard BNC female fitting, and the detectors may be used with a variety of crystal, bolometer, or thermistor elements, for absolute power measurements, as well as detection of relative power levels.

Although VSWR is low, impedance match can be improved by means of additional tuning such as E-H or slide-screw tuners. All models are designed for optimum VSWR with Narda model N610B bolometers, but good impedance matches can frequently be obtained with other bolometers and thermistors.

Data on VSWR with various elements is available from Narda, as well as a wide range of suitable detecting elements and crystals.

| BAND | FREQUENCY (kmc) | WAVEGUIDE O.D. (in.) | NARDA MODEL | DETECTING ELEMENTS | | | | | MAX. VSWR WITH N610B | CRY-STALS | PRICE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | BOLOMETERS | | | THERMISTORS | | | | |
| C | 3.95-5.85 | 2 x 1 | 513 | N610B | N821B | N605 | N333D or N333 | N334 | 1.25 | IN21 or IN23 | $95. |
| XN | 5.30-8.20 | 1½ x ¾ | 512 | N610B | N821B | N605 | N333D or N333 | N334 | 1.25 | IN23 | 90. |
| XB | 7.05-10.0 | 1¼ x ⅝ | 511 | N610B | N821B | N605 | N333D or N333 | N334 | 1.25 | IN23 | 85. |
| X | 8.20-12.4 | 1 x ½ | 510 | N610B | N821B | N605 | N333D or N333 | N334 | 1.25 | IN23 | 75. |
| KU | 12.4-18.0 | .702 x .391 | 509 | N610B | | N605 | N333D or N333 | | 2.00 | IN78 or IN23 | 110. |

**Tuneable Detectors for use with crystals only, available for millimeter bands 18,000 to 90,000 mc., from $125**

**Complete Coaxial and Waveguide Instrumentation for Microwave and UHF — including:**
200 to 90,000 mc.

DIRECTIONAL COUPLERS
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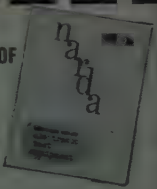
**the narda microwave corporation**
118-160 HERRICKS ROAD, MINEOLA, L. I., N. Y. • PIONEER 6-4650

**MAIL COUPON TODAY FOR FREE 1959 CATALOG AND NAME OF NEAREST REPRESENTATIVE**



The Narda Microwave Corporation
118-160 Herricks Road
Mineola, L. I., N. Y.
Dept. PIRE-10

NAME__________

COMPANY__________

ADDRESS__________

CITY__________ ZONE_____ STATE_____

*Designed for*

*Application*

MILLEN MALDEN U.S.A.
39016

A Really NEW
FLEXIBLE COUPLING
No. 39016

Incorporating features which have long been desired in a flexible coupling. No Back Lash—Higher Flexibility—Higher Breakdown Voltage—Smaller Diameter—Shorter Length—Higher Alignment Accuracy—Higher Resistance to Mechanical Shock—Solid Insulating Barrier Diaphragm—Molded as a Single Unit.

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MFG. CO., INC.

MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

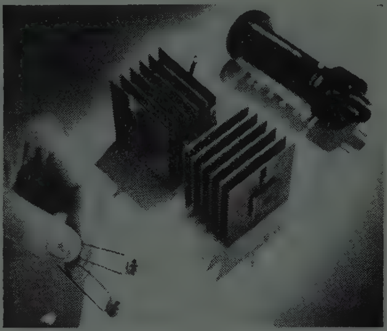
## NEWS
## New Products

**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.**

*(Continued from page 112A)*

### Silicon Rectifier

Latest of the semi-conductor devices developed by **P. R. Mallory & Co., Inc.**, 3029 E. Washington St., Indianapolis 6, Ind., the new Type T encapsulated silicon rectifier has a diffused junction and is designed for 85° C ambient temperature.



The new design produces several superior operating properties, including low reverse leakage current and low forward voltage drop. A new processing method for the wafer assures freedom from premature failure. By means of automatic classification equipment, 100 per cent of production is tested for surge current, forward drop and reverse leakage characteristics—assuring constant adherence to high quality standards.

In life testing of production samples, new Mallory silicon rectifiers have been operated above rated temperatures in all typical rectifier circuits for periods in excess of 2,000 hours. No failures have occurred after 1,500,000 switching cycles, and operating characteristics have remained virtually unchanged from original values.

The rectifiers are encapsulated and have been tested under MIL-Std. 202A, Method 106, which calls for 240 hours of humidity cycling. The units have passed 1,000 hours of this test without failure. Rectifiers have also been subjected to 250 hours of exposure to boiling water, with power alternately on and off for 8 and 16 hour periods respectively, without showing appreciable deterioration of characteristics.

Complete life test data has been compiled in all typical circuits, including full wave single phase bridge, half wave single phase, full wave doubler, voltage tripler, voltage quadrupler, twin quadrupler, full wave center tap transformer input, and full wave doubler transformer input.

Prices are substantially lower than previous units of comparable ratings.

*(Continued on page 116A)*

---

ELECTRONICS ENGINEERS · ELECTRONICS ENGINEERS

VACUUM TUBE
APPLICATION
ENGINEERS

If you have at least a bachelor's degree in engineering or physics and a minimum of 5 years' experience pertaining to design or use of vacuum tubes we can offer you a high-potential, supervisory position.

Responsibility begins with liaison activity in early tube development stages, proceeds through the manufacturing and procurement cycle and into final product usage. Highly advanced work involving specially ruggedized versions of subminiature receiving tubes, planar triodes, thyratrons, microwave tubes, special gas tubes and tubes unique to the atomic energy program.

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Bendix
KANSAS CITY

LONG RANGE
PRIME
CONTRACTOR
FOR THE A.E.C.

**Basic Facts About Bendix, Kansas City:**

- Technical management assures professional climate most conducive to your personal progress.
- Only a few minutes' drive from choice, new residential areas.
- Favorable climate, numerous recreational and cultural activities. Notably progressive city. Low cost of living.
- Uncrowded, highly-rated public schools.
- Assistance program for advanced study at nearby universities.

CONFIDENTIAL INQUIRY

MR. J. L. BRESLIN, Professional Personnel
BENDIX AVIATION CORP.
Box 303-BL, Kansas City, Mo.

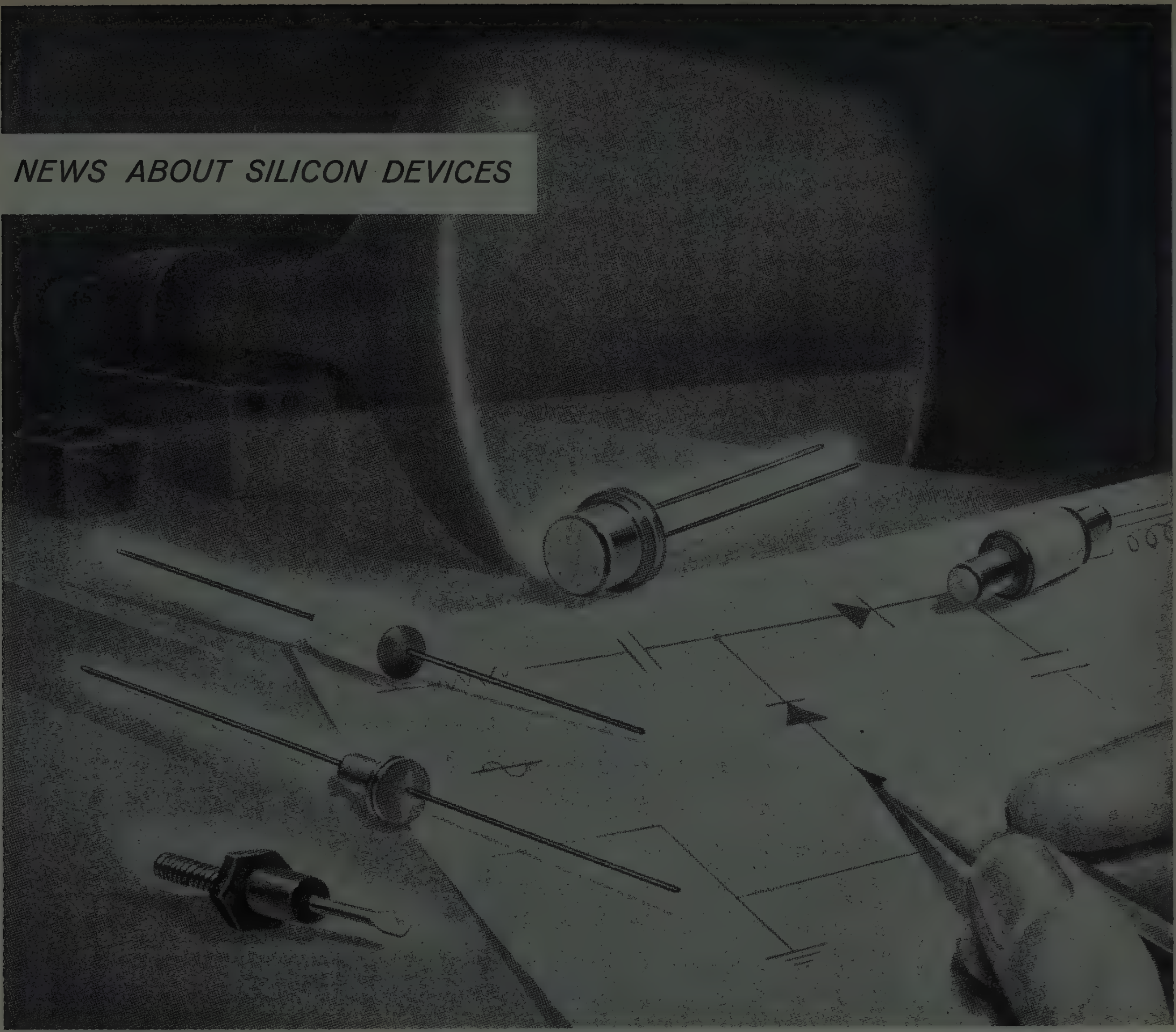
I am interested in receiving consideration for the position of Vacuum Tube Application Engineer.

Name ..........................................................

Street ................................ Phone ............

City .................................. State ............

## NEWS ABOUT SILICON DEVICES



Reverse current: $10^{-7}$ amp. Rectification ratio: 10,000,000:1

# Now... new efficiency for TV power supplies with dependable diodes of Du Pont Hyperpure Silicon

More efficient power supplies . . . savings in space and weight . . . important reasons why TV manufacturers are replacing conventional rectifying systems with silicon diodes. Today, several types of silicon diodes and rectifiers are readily available for TV circuits. TV manufacturers have tested silicon rectifiers and report no noticeable change in output voltage under continuous load conditions over long periods of time. Silicon components can operate in ambients from –65° to 150° C. They maintain excellent electrical stability and resist aging.

**Silicon components** have high shock and vibration limits. They are up to 99% efficient in units operated at 60 cps. and require little maintenance. Silicon cells permit a rectification ratio as high as 10 million to 1—almost negligible reverse conductance. Silicon bridges are available with ratings from 1 to 1,000 amperes and more than 600 volts rms.

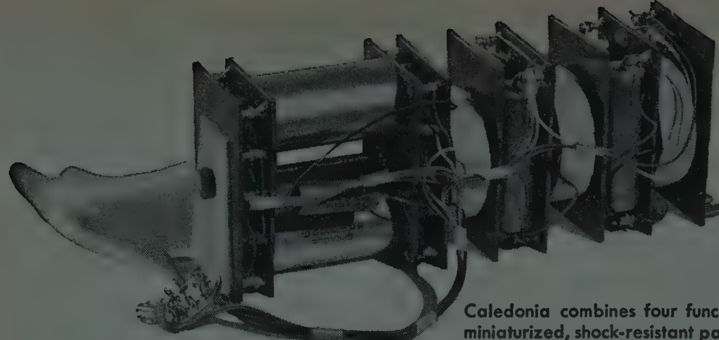
**Note to device manufacturers:** You can produce silicon transistors, rectifiers and diodes of the highest quality with Du Pont Hyperpure Silicon. It's now available in three grades for maximum efficiency and ease of use . . . with a purity range of 3 to 11 atoms of boron per billion. Technical information on crystal growing is available from Du Pont . . . pioneer producer of semiconductor-grade silicon.

**NEW BOOKLET ON DU PONT HYPERPURE SILICON**
You'll find our new, illustrated booklet about Hyperpure Silicon helpful and interesting—it describes the manufacture, properties and uses of Du Pont Hyperpure Silicon. Just drop us a card for your copy. E. I. du Pont de Nemours & Co. (Inc.), Pigments Department, Silicon Development Group, Wilmington 98, Delaware. (This offer limited to United States and Canada.)

PIGMENTS DEPARTMENT

DU PONT HYPERPURE SILICON
REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
. . . *THROUGH CHEMISTRY*



Caledonia combines four functions in miniaturized, shock-resistant package.

Electronics today is partly packaging

**PROBLEM:** Design a small (50 cubic in.) and light (3¾ lbs.) unit that contains:
1. a positive d.c. pulse selector
2. a negative d.c. pulse selector
3. a high level 60 cps band pass filter
4. a 400 cps detector circuit
(all with tight tolerances, naturally).

Design it to operate within the usual military environmental conditions, including high vibration and shock.

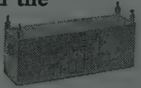
**SOLUTION:** We assembled the components shishkabob style. Then mounted the kabob in a metal case filled with an epoxy foam compound to hold the parts in a firm cushion.

**TIME ELAPSED:** From original assignment, through design to volume production—two months.

If such quick, dependable assistance in design and production can make your work more effective, we'll be glad to hear from you. We offer experience, good production facilities, and a recognized quality record.

CALEDONIA
ELECTRONICS AND TRANSFORMER CORPORATION

Dept. PI-10, Caledonia, N.Y. • In Canada: Hackbusch Electronics, Ltd., 23 Primrose Ave., Toronto 4, Ont.



Electrically Conductive Cloth

*A New Engineering Material for Many Applications in Electronics*

SUGGESTED USES:
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*Buy it by the yard and sew it to shape on any sewing machine. Or, have us sew it for you.*

WRITE OR PHONE
Swift
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10 Love Lane, Hartford 1, Conn.
JAckson 2-1181

## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 114A)*

### Television Transmitter for Medium Coverage

A space-saving, economical transmitter for medium-coverage television stations or as a standby unit for high power systems was announced today by **Broadcast and Television Equipment Dept., Radio Corporation of America,** 30 Rockefeller Plaza, New York 20, N. Y.

Designed primarily for VHF TV stations with effective radiated power requirements ranging from two to twenty kilowatts, the TT-2BH is said to provide excellent performance for both monochrome and color television broadcasting.

The new TT-2BH transmitter is housed in a cabinet which not only allows a saving in floor space but also offers accessibility to all components.

The new transmitter can be adapted for remote control operation with the addition of suitable terminal equipment.

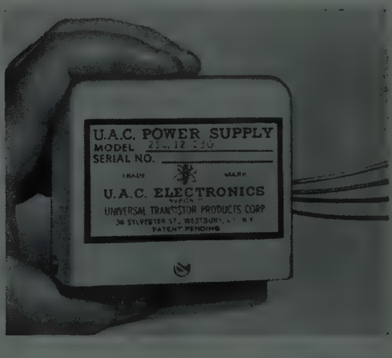
For the benefit of stations where space is at a premium, the transmitter cabinet stands only seven feet high and is just six feet long. The transmitter, with transformer filter assembly and blower, can be installed in a space 6- by 6½ feet.

All the principal meters of the TT-2BH are mounted in a sloping panel at the top of the cabinet.

Exciter and modulator units are adjustable from the front of the TT-2BH, making it unnecessary for the operator to enter the transmitter enclosure for routine maintenance on these units.

### Transistorized Receiver Power Supplies

A series of complete, compact, easily installed transistorized power supplies that provide the output required to operate receiver installations is now available from **Universal Transistor Products Corp.,** 17 Brooklyn Ave., Westbury, L. I., N. Y.



These fully transistorized, rectified, filtered units wire directly to battery and mobile equipment. They are direct replacements for conventional vibrator type power supplies.

*(Continued on page 118A)*

## COMPLETE LINE 125° C

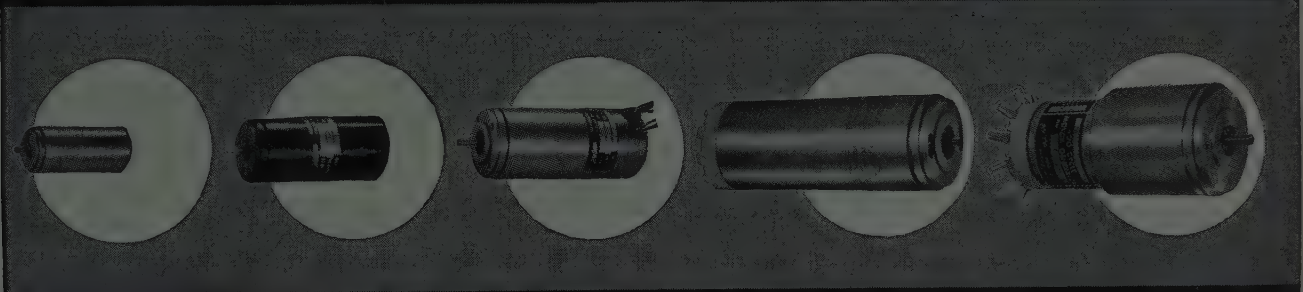
# SERVO MOTOR TACH GENERATORS

*to your precise specification*

**Oster**®

- Both Damping and Integrating types available with parameters to your requirement.
- Complete size range: 8, 10, 11, 15, 18. Can be designed with gear train.
- —54° C to +125° C ambient temperature range
- Designed to MIL-E-5272.
- Assembled under closely controlled environmental conditions.

Burton Browne Advertising



## 400 CPS SERVO MOTOR—TACHOMETER GENERATORS

| Oster Type | Size | Length Inches | Wt. Oz. | Rotor Inertia gm cm² | MOTOR |  |  |  |  | GENERATOR |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Rated Voltage Ø 1 | Rated Voltage Ø 2 | No load speed RPM | Watts per phase @ Stall | Stall Torque OZ. IN. | Excit. Volt. | Output Volts per 1000 RPM | Lin.% to 3600 RPM | Null MV | Phase Shift @25°C |
| 8MTG-6201-01 | 8 | 1.850 | 2.3 | 0.77 | 26 | 40/20 | 6,500 | 2.2 | 0.16 | 26 | 0.25 | 0.5 | 15 | ± 5° |
| *10MTG-6228-02 | 10 | 2.157 | 4.2 | 0.72 | 115 | 115/57 5 | 9,500 | 2.8 | 0.26 | 115 | 0.45 | 1.5 | 19 | ±10° |
| 10MTG-6229-12 | 10 | 2.100 | 2.9 | 1.09 | 33/16.5 | 52/26 | 9,500 | 3.0 | 0.28 | 26 | 0.45 | 1.5 | 13 | ±10° |
| *10MTG-6229-03 | 10 | 2.100 | 2.9 | 1.09 | 26 | 26 | 10,500 | 3.0 | 0.26 | 18 | 0.3 | 1.5 | 12 | ±10° |
| 10MTG-6229-15 | 10 | 2.100 | 2.9 | 1.09 | 26 | 26 | 10,500 | 3.0 | 0.26 | 26 | 0.3 | 1.5 | 12 | ±10° |
| *10MTG-6232-05 | 10 | 2.104 | 4.2 | 1.1 | 115 | 36/18 | 6,500 | 3.5 | 0.26 | 115 | 0.30 | 1.5 | 15 | ±10° |
| 11MTG-6251-13 | 11 | 2.531 | 7.0 | 1.3 | 115 | 115/57.5 | 6,500 | 3.5 | 0.63 | 115 | 0.55 | 0.5 | 19 | ±10° |
| 11MTG-6251-00 | 11 | 2.531 | 7.0 | 1.1 | 115 | 40/20 | 6,500 | 3.5 | 0.63 | 115 | 0.55 | 1 5 | 19 | ±10° |
| 11MTG-6254-01 | 11 | 2.200 | 6.0 | 1.1 | 115 | 115/57.5 | 6,500 | 3.5 | 0.63 | 115 | 0.55 | 1.5 | 19 | ±10° |
| 15MTG-6280-01 | 15 | 3.281 | 14.0 | 5.3 | 115 | 115/57.5 | 5,000 | 6.2 | 1.5 | 115 | 3.0 | 0.2 | 13 | ± 5° |
| †*15MTG-6276-03 | 15 | 3.875 | 15.0 | 4.4 | 115 | 57.5 | 8,500 | 5.8 | 0.70 | 115 | 2.75 | 0.2 | 13 | ± 0.5° |
| 18MTG-6302-02 | 18 | 3.680 | 20.0 | 5.7 | 115 | 115/57.5 | 9,000 | 16.0 | 2.7 | 115 | 3.0 | 0.2 | 13 | ± 5° |
| 18MTG-6302-04 | 18 | 3.680 | 20.0 | 5.7 | 115 | 115/57.5 | 4,800 | 9.2 | 2.4 | 115 | 3.0 | 0.2 | 13 | ± 5° |

*These units designed for 85°C ambient but same characteristics can be designed for 125°C. †Additional 21.4 watts for heater, the values given are independent of ambient temperature.

Other products include servos, synchros, resolvers, motor-gear-trains, AC drive motors, DC motors, servo mechanism assemblies, reference and tachometer generators, servo torque units, actuators and motor driven blower and fan assemblies.

**John Oster** MANUFACTURING CO.
*Your Rotating Equipment Specialist*
Avionic Division
Racine, Wisconsin

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5333 So. Sepulveda Blvd.
Culver City, California
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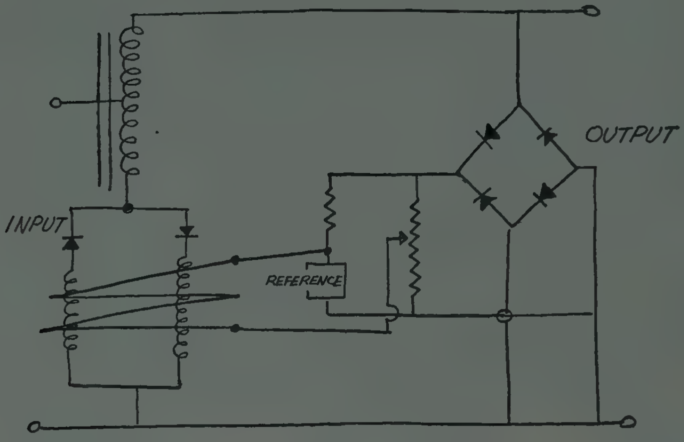
**Engineers For Advanced Projects:** Interesting, varied work on designing transistor circuits and servo mechanisms. Contact Mr. Robert Burns, Personnel Manager, in confidence.

# MEET MIL SPEC E4970



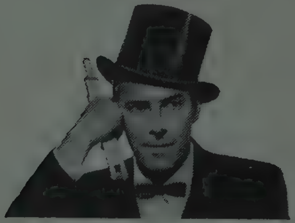
SIMPLIFIED MAGNETIC AMPLIFIER REGULATOR

Meeting military specifications is practically an everyday occurrence at Raytheon. But each one has a special interest.

We thought you might be interested in how a magnetic-amplifier regulator met MIL SPEC E4970. The details are available to the more academically inclined. We will simply relate the results:

| | |
|---|---|
| Service: | 400 cycles |
| Power: | 900 watts |
| Input: | 95 to 125 volts |
| Output: | 115 volts ±½% |
| Harmonic distortion: | ±3% |

The next time you have to meet military or your own rigid specifications, we'll be happy to go along.



Our slide rule and tuxedo are ready at a moment's notice. Simply contact:

VOLTAGE REGULATOR MAN
Raytheon Manufacturing Company
Magnetic Components Department
Section 6120
Waltham 54, Massachusetts

RAYTHEON
*Excellence in Electronics*

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 116A)*

Features include operating life in excess of 10,000 hours, efficiency to 85 per cent, rating for continuous duty, extremely low ripple, elimination of high current starting surges and of moving parts, and of vibrator hash.

Standard units are available through electronic parts wholesalers, or in quantity from the manufacturer in a wide variety of current ratings from 6vdc or 12vdc input.

A typical unit, model 250/12/130 produces 250 vdc at 130 ma from 12 vdc input in a 2×3½×3 inch package. It weighs 12 ounces, and costs $65.00.

## Magnetic Amplifier

The Model 405 precision magnetic amplifier package has just been announced by **Acromag, Inc.**, 22519 Telegraph Rd., Detroit 41, Michigan. The new Model 405 amplifier is designed to drive electrohydraulic servo valves used in missiles, aircraft, and industrial control system.

TYPE 405
acromag
PRECISION
MAGNETIC AMPLIFIER
ACROMAG, INCORPORATED
DETROIT, MICHIGAN - U.S.A.

A special feature of the new amplifier is its response characteristics to 50 cps which permits it to be used in critical response systems.

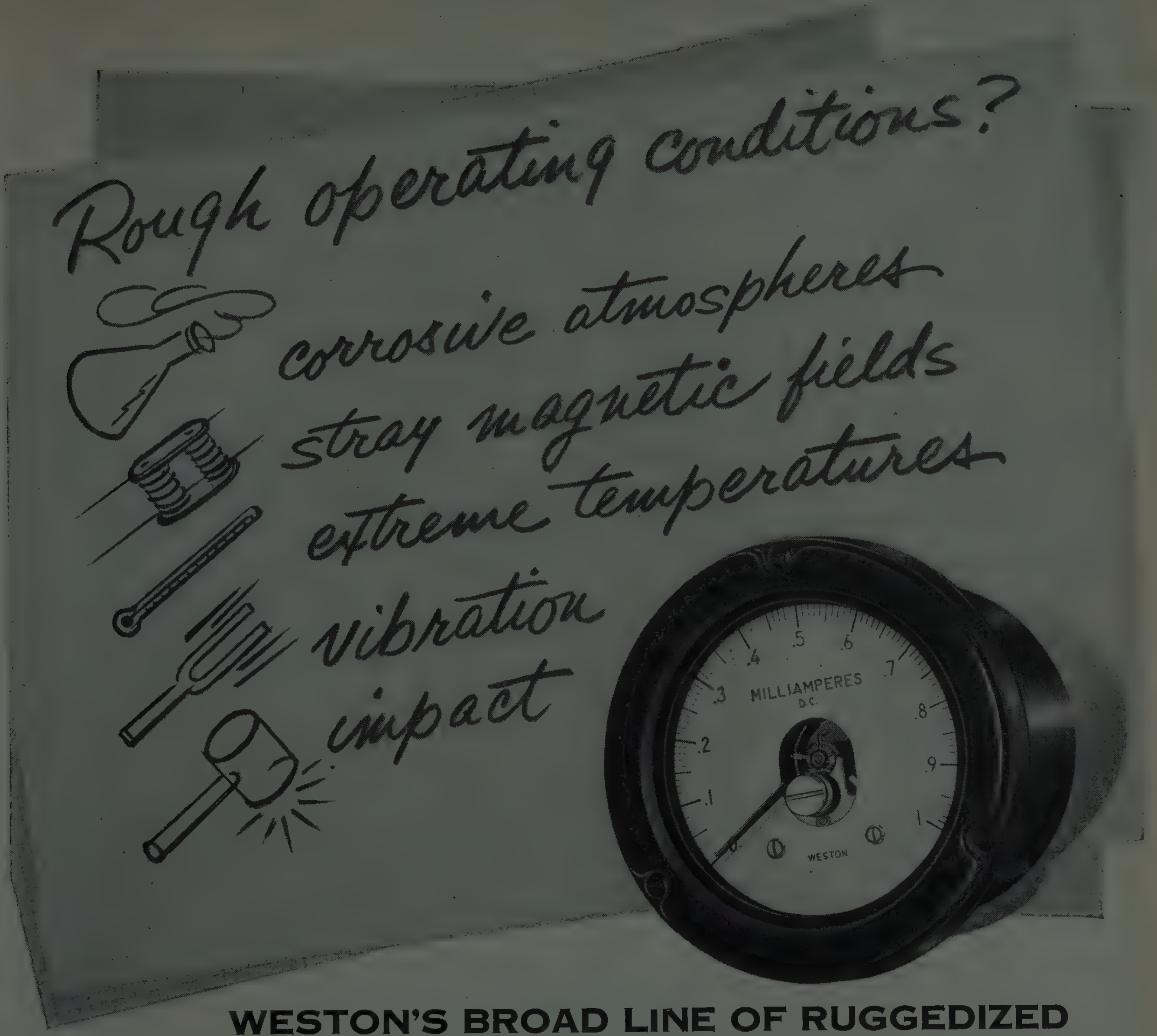
The amplifier is hermetically sealed in a self-contained, plug-in package. External gain and balance controls are not required, as the amplifier is inherently stable.

The 405 requires less than 3.0 watts of 115 volt 400 cps power, and weighs less than 9.5 ounces. It withstands temperatures of up to 125°C and shocks of 100 G's.

A detailed application and specification sheet is available from R. G. Hennings, Acromag, Inc.

*(Continued on page 121A)*

WESTON INSTRUMENTS: STANDARDS OF STABILITY IN SCIENCE AND INDUSTRY



## WESTON'S BROAD LINE OF RUGGEDIZED INSTRUMENTS WILL TAKE THEM EASILY IN STRIDE

New design concepts, new materials and new production techniques . . . these are the ingredients of Weston's '58 line of Ruggedized Instruments. Now, more than ever, they insure dependable, accurate service under extremes of shock, vibration, temperature, humidity and general abuse.

Mechanisms are mounted on metal decks. The decks and terminals are then molded into a specially compounded, shock-resistant rubber. This results in a well-insulated, leakproof, and virtually breakproof seal. Damage from impact to jewels and pivots is eliminated through spring-backed mounting. Tough plastic windows make the use of zero correctors practical. The entire mechanism is housed in a rigid steel case which provides excellent shielding against external magnetic fields. The instruments may be mounted interchangeably on either magnetic or non-magnetic panels without loss of accuracy.

Consult your local Weston representative for complete details . . . or write for Catalog A-38. Address: Weston Instruments, Division of Daystrom, Inc., Newark 12, N. J. *In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 10, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.*

*Take advantage of Weston's unusually fast prototype service!*

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*Instruments*

A DAYSTROM UNIT

# STODDART

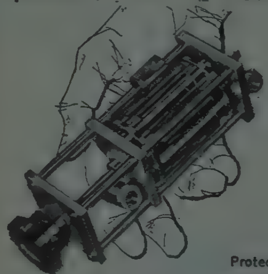
## COAXIAL ATTENUATORS AND TERMINATIONS

*made with exclusive Stoddart Filmistors for highly accurate and stable resistive values from dc to 3000 mc.*

2, 6 and 10-position

**TURRET ATTENUATORS**

with simple "PULL-TURN-PUSH" operation, small and rugged.



Protected under Stoddart Patents

## ATTENUATOR PADS

Available in any conceivable combination of male and female Type C and Type N connectors. Maximum length of 3" for any attenuation value.

GENERAL SPECIFICATIONS

VSWR: Less than 1.2 to 3000 mc.

Characteristic Impedance: 50 ohms.

Attenuation Value: Any value from 0 db to 60 db including fractional values.

Accuracy: ±0.5 db; values above 50 db have rated accuracy of attenuation through 1000 mc only.

Power Rating: 1.0 watt sine wave.

## COAXIAL TERMINATIONS

Small-stable-50 or 70 ohms

½-Watt: 50 ohms impedance, TNC or BNC connectors, dc to 1000 mc, VSWR less than 1.2.

1-Watt: 50 ohms impedance, dc to 3000 mc or dc to 7000 mc, Type N or Type C connectors, male or female; VSWR less than 1.2, 70 ohm, Type N, male or female terminations available.

Fast delivery on all items.
Send for complete literature.

**STODDART**
AIRCRAFT RADIO CO., INC.
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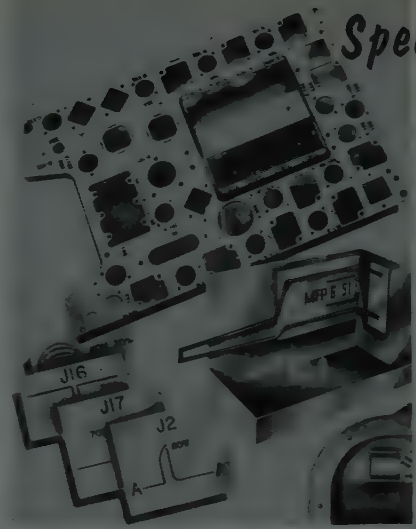
HOllywood 4-9292

# PRECISION STENCILS



*Speed your operations*

Inexperienced workers can quickly mark complete parts in a matter of seconds. They will give you more units per hour, with fewer rejects. Average worker can assemble even difficult jobs easily, surely and quickly once they are legibly and accurately marked.

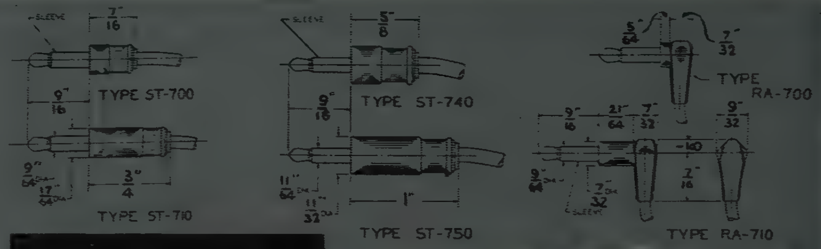
Metal stencils made to fit any size or shape of part. Interchangeable, too, if you desire.

## MARKING INKS

Skillfully blended inks in varieties of colors for both permanent and temporary marking.

ANY SIZE
•
ANY COLOR

**JAS. H. MATTHEWS & CO.**
3922 Forbes Ave., Pittsburgh 13, Pa.
OFFICES IN PRINCIPAL CITIES
WRITE, CALL, OR TWX PG 424



UNUSUALLY SMALL

**SWITCHCRAFT® INC.**

## MOLDED "TINI-PLUG" CABLE ASSEMBLIES

### *Your Solution to a Time Consuming Job . . .*

It is no longer necessary for the equipment manufacturer to purchase connectors, plugs, and cables separately, and make up their own assemblies. Switchcraft does it for you.

TYPE RA—Right Angle Tini Phone Plug (2 sizes) for equipment where it is desirable to bring out the cable at right angles to the plug "finger." Suitable where equipment Jack is recessed.

TYPE ST—Straight Tini Phone Plug (4 sizes) with a convenient finger grip on the handle but short enough to fit all equipment.

**Featuring:**

- **Attractive Switchcraft Design.**
- **Completely Shielded.**
- **Built to requirements.**
- **Terminations as required.**

*Send for catalog supplement S-592.*

**SWITCHCRAFT® INC.**

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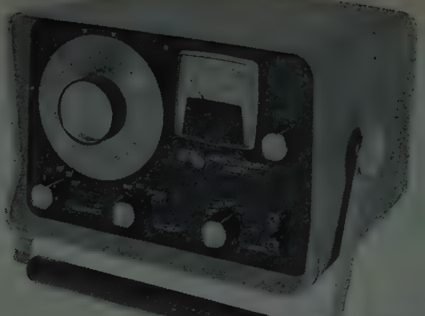
Canadian Rep: Atlas Radio Corp., Ltd., 50 Wingold Avenue, Toronto, Ontario new from SIE

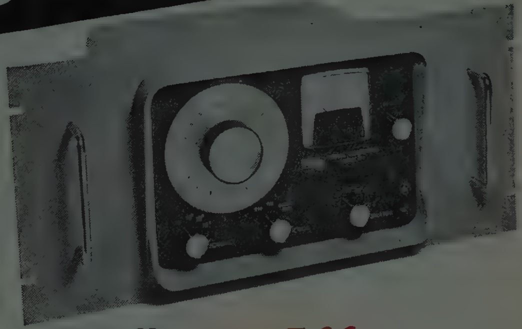
output meter and calibrated attenuator on front panel



portable • tiltable • rackable

RANGE: 2 cps — 200 kcps
ACCURACY: 2%
OUTPUT: 1 volt
DISTORTION: less than 1%

N-1 signal generator



Another in the line of SIE Advanced Design Instruments, human engineered for operating efficiency. Easier to set up • Easier to read • Adjustable viewing angle • Parallax free vernier tuning • Large, easily set control knobs • Protected front panel • Convenient carrying handle.

BENCH OR RACK MODEL 275.00 f.o.b. Houston, Tex

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## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 118A)*

### Transistors for Data Processing Systems

A pair of hermetically sealed NPN germanium-alloy transistors designed for data processing applications where core drivers operate up to 400 ma current levels has been announced by **Sylvania Electric Products Inc.**, Woburn, Mass.

Designated Types 2N576 and 2N576A, both transistors feature a junction temperature of 100°C total dissipation of 200 mw and collector current of 400 ma.

Type 2N576 has a 20-volt collector to base voltage. Type 2N576A has a collector to base voltage of 40-volts.

Both types employ a JETEC TO-5 case with the base connected to the case internally.

### Applied Physics Completes Move

Howard Cary, president of **Applied Physics Corporation**, today announced that all phases of the company's move into its new quarters at 2724 S. Peck Rd., Monrovia, Calif., have been completed. Cary stated that the five-year old, 50,000 square

*(Continued on page 122A)*

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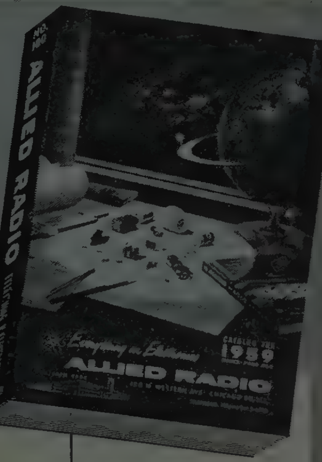
ALLIED'S COMPLETE 452-PAGE 1959 CATALOG



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ELECTRONIC SUPPLIES FOR INDUSTRY

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- AN Connectors
- Racks & Chassis
- Tools & Hardware
- KNIGHT Public Address & Paging Systems

OEM prices available on quantity purchases

ALLIED RADIO
100 N. Western Ave., Dept. 35-K8
Chicago 80, Illinois

Send for FREE Catalog

OUR 38th YEAR

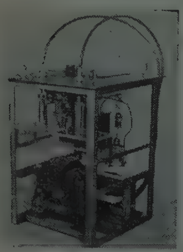
**HIGH** Voltage Quality Reliability

**POWER SUPPLIES**

**AND**

**TRANSFORMERS**

***Series "O" Oil Insulated Tank Units***



- Reversible Polarity
- Shielded Polyethylene Output Cables
- Low Corona
- Sealed Oil Tight, Dust Free Tank
- Quiet Long Life Operation

HIGH VOLTAGE POWER SUPPLIES

From 2.5 to 200 KV up to 30 KVA. Oil, air or epoxy insulation.

**CONTROLS**

For rack and panel mount. Optional control features, alarm circuits or protective arrangements to suit your requirements on special order.

| MODEL | OUTPUT | RECT. | RIPPLE | DIMENSIONS |
|---|---|---|---|---|
| 50-5-1* | 50KV 5MA | T | .3%/MA | 16½x16½x22 |
| 50-7-1* | 50KV 7MA | T | .3%/MA | 16½x16½x22 |
| 40-10-1* | 40KV 10MA | T | .4%/MA | 16½x16½x22 |
| 30-3-2 | 30KV 3MA | T | .5%/MA | 10x12½x13 |
| 30-3-1* | 80KV 3MA | Sel. | .001%/MA | 16½x16½x22 |
| 30-6-1 | 30KV 6MA | T | .5%/MA | 10x12½x13 |
| 30-20-1* | 30KV 20MA | T | .5%/MA | 16½x16½x22 |
| 20-25-1* | 20KV 25MA | T | .75%/MA | 16½x16½x22 |

*For 110/220 operation, all others 110 Volts 50/60 Cycles.

***Compact High Voltage Power Supplies***

*Extremely compact design for mounting on chassis.*

- *Selenium Rectifiers*
- *Low Ripple*
- *Reversible Polarity*
- *Shielded Output Cables*
- *Hermetically Sealed Can*
- *Epoxy Filled*
- *INPUT: 115 Volts—60 to 400 Cycles*

| MODEL NO. | OUTPUT | DIMENSION<br>W D H |
|---|---|---|
| 2.5-2-1 | 2.5KV-2MA | 3 x 2½ x 4½ |
| 5-2-1 | 5KV-2MA | 3 x 3½ x 4½ |
| 10-1-1 | 10KV-1.25MA | 3 x 3½ x 5½ |

*For additional information write Dept. P*

**DEL ELECTRONICS CORP.**

Tel. OWens 9-3232

521 Homestead Ave., Mt. Vernon, N.Y.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 121A)*

foot building (pictured) provides a substantial increase in space over that formerly occupied by the company in three Pasadena locations.

Applied Physics began in Pasadena during January of 1946. It developed the first commercial recording spectrophotometer, widely used for making chemical analyses of many materials. Since that time, the company has grown steadily and expanded its product line to include several kinds of precision instruments.

## 4-Digit DC Voltmeter

The new DVA-400 DC Digital Voltmeter was recently announced by **Electro-Instruments, Inc.**, 3540 Aero Court, San Diego 11, Calif., features transistorized circuits and modular construction. The instrument combines a universal Power b Module and a four-digit Switch Module to provide a complete voltmeter for measuring dc voltages between 0.001 and 1100 volts, to ±(0.01 per cent and 1 digit) accuracy.

Other specifications of the new instrument include automatic ranging and polarity, and one second average balance time.

For further information contact Electro Instruments, Inc.

## Folded Hybrid T'S Catalog

**Microwave Development Laboratories, Inc.**, 92 Broad St., Babson Park 57, Wellesley, Mass., has just released a 6 page two color catalog No. 850 which provides an up-to-date guide for the selection of precision cast and fabrication E Plane and H Plane Folded Hybrid T'S. For a free catalog write to the firm.

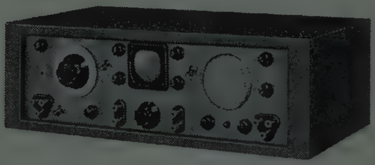
*(Continued on page 138A)*

ACCURACIES BETTER THAN 1 PART IN 50 MILLION are free!

WHY NOT USE THEM!

The standard time and frequency transmissions of the National Bureau of Standards radio stations WWV and WWVH provide an invaluable service to laboratories and experimenters throughout the world. Extremely precise (normal transmission stability is within 1 part in $10^9$ at WWV and 5 parts in $10^9$ at WWVH) audio and radio frequency standards, as well as accurate time intervals and radio frequency propagation warnings, are placed at the disposal of anyone having a receiver capable of tuning to one or more of the transmitting frequencies. Proper use of these facilities can be made to supplement the instrumentation of any laboratory.

The Model WWVC Standard Frequency Comparator is just such an instrument . . . a highly sensitive crystal-controlled radio receiver utilizing WWV and WWVH transmissions.



MODEL WWVC COMPARATOR

A 5-position dial switches *precisely* to any Standard Frequency—2.5, 5, 10, 15, or 20MC. It features built-in oscilloscope and speaker, comparator function selector, Collins plug-in filter for high selectivity, automatic gain and volume controls and adjustable threshold control which eliminates noise and other modulation in tick position.

Send for bulletin #557, "Using Standard Time and Frequency Broadcasts"

SPECIFIC PRODUCTS

Box 425, 21051 Costanso
Woodland Hills, Calif.

*In Engineering—meet a man who gets results*

**Painting pictures, designing missile systems . . .**
**creativity typifies the General Mills engineer**

Meet Dr. Howard Baller, art collector, amateur painter, and Director of Engineering at the Mechanical Division of General Mills. At the office or at the easel, creativity is the mark of his endeavor.

This same creativity is the distinguishing feature of the well equipped, highly talented engineering department he directs. It is seen in every staff member—reflected in every one of their projects, some of which include . . .

| SYSTEMS | SUBSYSTEMS |
|---|---|
| Airborne Early Warning | Inertial Guidance and Navigation |
| Missile | Special Purpose Electro-mechanical Analogue Computers |
| Geodetic and Survey | Special Purpose Digital Computers |
| Ground Support Equipment | Microwave Radar and Beacons |
| Naval Ordnance | Fuzing and Arming Devices |
| Space Vehicle Guidance | |

We team creative engineering with intensive research and fine precision manufacturing to serve the nation's most exacting customers. We'd like to serve you.

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MECHANICAL DIVISION

1620 Central Avenue • Minneapolis 13, Minnesota

*Intensive Research • Creative Engineering • Precision Manufacturing*

General Mills

Dr. Baller has been engaged in a wide variety of advanced engineering projects for 18 years. At General Mills he directs and coordinates activities of an excellent staff of unusually capable engineers. Dr. Baller is one more reason our customers say, "At General Mills, we get results."

**WARHEAD**

*circa 400 A. D.*

Centuries ago, the Indians of New Mexico designed and developed warheads like this one.

Today, we at Sandia Corporation do very much the same job —but we call it research and development in the ordnance phases of nuclear weapons for the Atomic Energy Commission.

The people who made these primitive warheads also applied many of the same skills and techniques to produce implements of peace—grinding stones, knives, needles, and quite a few others.

Here again, we at Sandia follow a similar pattern. In the pursuit of our main task, we study many things in widely-varied fields ranging from nuclear phenomena to numbers theory, from meteorology to metal-working. We learn basic scientific facts and advanced techniques that have important applications far removed from nuclear weapons.

We probe new frontiers of science and engineering. We meet and solve challenging problems in many areas of advanced technology. These are activities which require the services of outstanding engineers and scientists in many fields in our work to maintain our nation's defensive strength.

We have such men—both at Sandia in Albuquerque and at our branch laboratory in Livermore, California. But we need more—at the highest academic and experience levels.

If you are interested in exploring the exceptional opportunities for professional growth and advancement with Sandia Corporation, please write to Staff Employment Section 554C.

SANDIA
CORPORATION
ALBUQUERQUE, NEW MEXICO

# Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

**The Institute reserves the right to refuse any announcement without giving a reason for the refusal.**

**Proceedings of the IRE**
**1 East 79th St., New York 21, N.Y.**

### PHYSICISTS, CHEMISTS, ENGINEERS

Positions now open for research in each of the following fields: gas discharges, electron tube devices including storage tubes, radiation effects on dielectrics, and semiconductors. Send resume to Radiation Research Corp., 1114 First Ave., New York 21, N.Y.

### PROJECT ENGINEERS

Immediate openings are available for Project Engineers in microwave communications, instrumentation and telemetry. Openings are also available for young graduate engineers with 1 to 5 years experience. Excellent employee benefits with young growing company. Send resume to Ling Systems Inc. 11949 Vose St., North Hollywood, Calif.

### ELECTRONIC ENGINEERS

Electronic Engineer to teach lecture and laboratory courses. Up-to-date knowledge of the field required. Working and living conditions excellent; salary and opportunity very attractive. Write to Dean of Engineering, California State Polytechnic College, San Luis Obispo, Calif.

### ENGINEER

Engineer to open branch office of Manufacturers Reps. Agency in upper New York State or Boston area, on a partnership basis. Engineering background required, digital background desirable but not essential. Principal has topnotch manufacturers of digital and analog systems and components. Wants to expand. Please send resume to Box 1078.

### TEACHERS

Excellent opportunity is available in a new expanding department. Location is at medium sized university in the midwest devoted primarily to undergraduate teaching. Rank and salary commensurate with qualifications. Appointment is now available. Send complete resume to Box 1079.

### ASSOCIATE PROFESSOR

Associate Professor of Electrical Engineering at medium size state university in the middle west. Ph.D. or D.Sc. and U.S. citizenship required. Fields of specialization in instrumentation, propagation, microwaves and/or antennas desired. 9 months combined teaching and research, salary about $10,000. Summer research employment available. Box 1080.

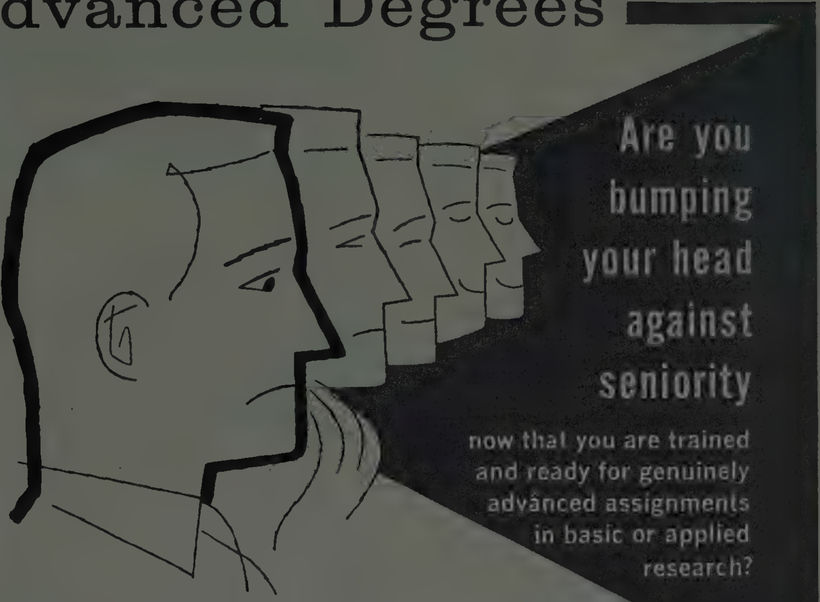
### ELECTRONIC ENGINEER

Design and development work in nuclear research for men at all degree levels with experience in the following areas: transistors, tube cir-

*(Continued on page 128A)*

PHYSICISTS...MATHEMATICIANS...EE's

Scientists and Mathematicians with Advanced Degrees



With the best will in the world, every company cannot provide deserved promotion for all its good men.

Company *growth* is essential to staff advancement.

Company emphasis on research and development in forward areas is necessary, to provide able men with the assignments and facilities that make scientific discoveries possible.

IF YOU FIND YOUR PROGRESS SLOWED at this time, look into the opportunities available for highly trained, creative men in:

**Basic and Applied Research at SYLVANIA'S New Amherst, N. Y. Engineering Lab.**

Broad investigations leading to advances in communications concepts and techniques are under way in such areas as:

• Interplanetary Communications Systems • Composition of Space • Statistical analysis of noise & fading • Optimum signals for communication channels • Efficient applications of redundancy • Physics of the communication channel • Error correction & error detection • Theoretical & applied probability theory • Physical basis of communication • Wave propagation in missile & satellite environments.

The Amherst Laboratory is expanding. New facilities were completed only a few months ago and plans call for a substantial increase in the professional staff. There is practically no limit to how far an original thinker can go in advanced communications with Sylvania.

*Sylvania is seeking* SCIENTISTS AND ENGINEERS WHO CAN DEFINE THEIR OWN PROBLEMS (rather than solve problems formulated by others) AND WORK WITH A MINIMUM OF SUPERVISION.

AN ADVANCED DEGREE IS REGARDED AS HIGHLY DESIRABLE FOR THE WORK OUTLINED. Also depth of experience in such areas as: Experimental & Theoretical Physics, Electronic Systems Development, Information Theory, Probability Theory, Game Theory, Stochastic Processes.

*Please Write to*: Dr. Robert Malm
**Amherst Engineering Laboratory**
ELECTRONIC SYSTEMS DIVISION
**SYLVANIA**
SYLVANIA ELECTRIC PRODUCTS INC.
1140 Wehrle Drive, Amherst 21, New York

# Sylvania's Expanding Mountain View Laboratories Offer You...

**CREATIVE CHALLENGE** TO APPLY YOUR ABILITIES TO CONCEPTION AND DEVELOPMENT OF COMPLEX NEW SYSTEMS AND COMPONENTS ADVANCING THE STATE OF THE ART. **ADVANCEMENT** BASED ON INDIVIDUAL CONTRIBUTION WITH FULL AUTHORITY TO EFFECTIVELY CARRY OUT RESPONSIBILITIES. **CALIFORNIA** SUBURBAN LIVING ON THE SAN FRANCISCO BAY PENINSULA.

---

### SYSTEM STUDIES

Analysis & logical design of digital computer circuits. 7 or more years experience desirable in varied phases of electronic systems analysis with emphasis on computer logic. Advanced degrees desirable.

**RECONNAISSANCE SYSTEMS LAB**

R&D and Fabrication of reconnaissance systems & equipment.

### COMPUTERS & DATA HANDLING

D&D of transistorized circuits & high speed digital computer elements. Openings at all levels for engineers with experience in computer design & transistorized circuits.

### ELECTRONIC PACKAGING

Packaging of airborne electronic subminiaturized equipment. 7 or more years experience in electromechanical packaging of electronic equipment desired.

### RELIABILITY

Conduct statistical analysis of complex electronic circuits to determine reliability characteristics of the system. Degree in Statistics desirable with 5 or more years experience in some phases of electronics reliability studies.

### DEVELOPMENT ENGINEERING

To perform circuit & equipment design and development in the areas of direction finding, data handling, passive detection, receivers, RF circuits and antennas.

**MICROWAVE TUBE LABORATORY**

R&D and Production of special purpose microwave tubes.

### TUBE ENGINEERS

Design, construction & testing of Traveling Wave tubes. Minimum 1 year experience in test & evaluation of TWT's.

### TUBE APPLICATION ENGINEERS

Familiarity with tube specifications & test procedures. To work directly with customers to satisfy their requirements. Requires varied background in electronics & microwave tubes.

### SR MECHANICAL ENGINEERS

Perform mechanical design & test of tubes, components & tooling. 5 years experience in mechanical design of vacuum tubes, solenoids & microwave plumbing or developing, testing & evaluating special purpose tubes.

### TUBE PRODUCTION ENGINEERS

Construction & manufacture of special purpose microwave tubes. 3-5 years experience in vacuum tube production technique.

### MICROWAVE ENGINEERS

Plan & perform microwave experiments on ferrites & gaseous electronic phenomena in relation to development of microwave control devices. Experience in microwave transmission & measurement required with experience in high vacuum systems desirable.

**MICROWAVE PHYSICS LAB**

Research & advanced development: areas of magnetic ferrites & gaseous electron physics.

### RESEARCH SCIENTISTS

To perform theoretical analysis & conduct experiments in production of ultra-violet radiation, microwave breakdown in molecular gases & the transmission of electromagnetic waves through ionized shock fronts & plasmas. Background in electromagnetic theory, plasma physics, gas discharges, & atomic physics desirable, as well as knowledge of microwave measurement techniques & vacuum systems. Advanced degrees desirable.

**ELECTRONIC DEFENSE LAB**

R&D and Fabrication of electronic countermeasures systems & equipment.

### SYSTEMS ENGINEERS

With special interest in advanced systems planning for electronic countermeasures systems, systems analysis, experimental & theoretical susceptibility studies, aerodynamics applied to problems by use of analog computer simulation, applied statistics involving decision, theoretic techniques, laboratory test & integration of electronic systems. Academic work beyond bachelor degree or research experience in experimental physics, statistics or electronics desirable.

### FIELD ENGINEERS

To work in field on varied domestic & foreign assignments, to install electronic equipment, perform engineering tests, train military personnel & provide engineering assistance to military commanders. BS degree required plus industrial or military electronics experience.

### ELECTRONIC ENGINEERS

Research & advanced development in the fields of electronic countermeasures & electronic systems; particular areas of activity are transmitters, receivers, analyzers, direction finders, data handling, RF circuits & antennas. Experience and/or advanced academic training are especially desirable.

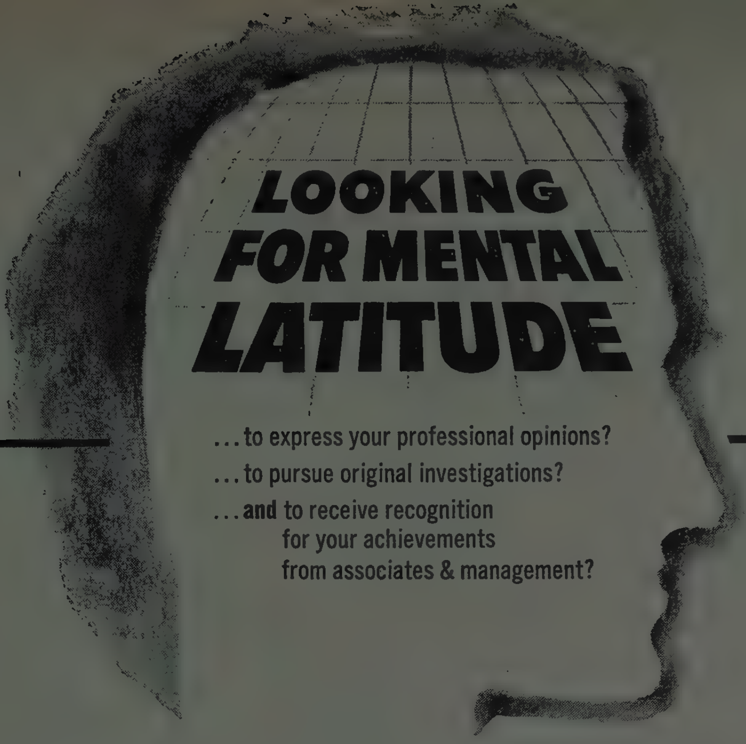
### MECHANICAL DESIGN ENGINEERS

Electromechanical design experience, preferably in microwave systems, equipment & packaging. Ability to originate & direct design, to follow through projects. Also engineering experience on high performance precision hydraulic drive & servo control, as in large antenna pedestals. Requires proven creative ability.

Please send your resume to
Mr. J. C. Richards

**SYLVANIA**

SYLVANIA ELECTRIC PRODUCTS INC.
P.O. Box 188—Mountain View, California



# LOOKING FOR MENTAL LATITUDE

*Engineers*

*Scientists*

...to express your professional opinions?
...to pursue original investigations?
...and to receive recognition
for your achievements
from associates & management?

Mental freedom is not confined within rigid boundaries at Sylvania's Waltham Laboratories. Scientists and engineers collaborate—but their individual contributions stand out clearly, unobscured by "team" activity.

Men of high professional attainments will find the latitude they seek for original thinking at Sylvania. Taking seemingly impossible projects and creating systems that meet—and surpass—the most difficult requirements is the type of challenge and achievement characteristic of the Waltham Laboratories. Among projects now in progress is the High Speed Data Processing Phase of BMEWS, the USAF's Ballistic Missile Early Warning System.

**IF YOU HAVE ABILITY SYLVANIA OFFERS OPPORTUNITY**

### DATA PROCESSING LABORATORY

*(where MOBIDIC, a general purpose digital computer was designed & developed for Sylvania Electronic Systems)*

- Sr. Development Engineers
- Sr. Packaging Engineers
- Project Engineers
- Sr. Logical Design Engineers
- Engineers with experience in Radar Data Handling and Display

*(Previous digital data processing experience is important for most assignments.)*

### AVIONICS LABORATORY

- Microwave components design including multi-channel filters incorporating fast-acting microwave switches
- Flush-mounted broad band airborne microwave antennas
- Transistor circuit design & development

### MISSILE SYSTEMS LABORATORY

- Advanced development on complex VHF and UHF radar systems
- Systems analysis and synthesis of complex radars, their design and simulation
- Systems simulation, mathematical analysis and guidance system design
- Systems studies in aeroelasticity, flutter, aerodynamics and other aeronautical-mechanical-engineering pursuits

### APPLIED RESEARCH LABORATORY

- Research & Systems Application in Counter-Countermeasures, Operations Research, Analysis & Applied Physics

Interview & relocation expenses paid by Sylvania. Inquiries will be answered within 2 weeks. Convenient Saturday interviews arranged.

*Please send resume to* ERLING MOSTUE
**WALTHAM LABORATORIES • Sylvania Electronic Systems**
*A division of*
**SYLVANIA**
SYLVANIA ELECTRIC PRODUCTS INC.
100-B First Avenue—Waltham 54, Massachusetts

# Electronic scientists-engineers

NAA-Columbus is expanding its electronic staff in the Advanced Design, Systems Management and Systems Research Groups. Career positions available in the fields of:

**ECM:** Perform analysis and development of advanced airborne electronic counter-measure systems including analysis of the weapon systems in its tactical environment.

**RADAR ANTENNA:** Assume responsibility for theoretical, experimental and system analysis of advanced radar antenna techniques including electronic scanning.

**DATA PROCESSING:** To analyze information sources, communication rates and processing of information, equation mechanization, and computer programming for airborne and ground processing systems. Must know digital to analog or analog to digital conversion techniques.

If you have an advanced degree and/or several years experience and are interested in moving up from components to entire systems, write to:

**Engineering Personnel, Box PR580**
**North American Aviation, Inc.**
**4300 East Fifth Avenue**
**Columbus 16, Ohio**

THE COLUMBUS DIVISION OF

**NORTH AMERICAN AVIATION, INC.**

*NAA-Columbus . . . home of the T2J Jet Trainer and the A3J Vigilante.*

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## Positions Open

(Continued from page 125A)

cuitry, pulse techniques, industrial electronics, instrumentation, reactor control systems, guided missile control systems and telemetering data reduction. Apply University of California Radiation Lab. P.O. Box 808, Livermore, California. (U.S. citizenship required)

### COMPUTER ENGINEERS

E/E's, M/E's and Physicists in the areas of: Reliability, Systems Analysis, Magnetic Memory Cores, Circuit Design, Prototype Systems Testing, Specifications, etc. Salaries: $[illegible]-$[illegible]. Write to Mr. Aston, [illegible] Management Consultants, 25 East 73 St., New York 21, N.Y.

### RESEARCH ASSOCIATE U.B.C.

Research Associate to undertake and direct research in microwave circuits and antennas. Duties include post-graduate lectures in Applied Electromagnetic theory and some undergraduate instruction. Inquiry should be sent to Dr. F. Noakes, Head, Dept. of Electrical Engineering, University of British Columbia, Vancouver 8, B.C., Canada.

### CONSULTANT

Manufacturer in northern New Jersey is interested in obtaining outside consultant having thorough background and experience in design and development of delay lines and pulse transformers. Box 1081.

(Continued on page 132A)

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**Exceptional opportunities for**

## ELECTRONIC ENGINEERS and PHYSICISTS

**A limited number of positions are open on our staff for senior and junior electronic engineers and physicists, to conduct applied research and development in advanced data processing systems and electronic circuitry. PRA's projects are unusually interesting and challenging, sponsored by the Government and private industry. Salaries at high industrial levels, commensurate with experience and ability. Excellent working conditions. U. S. citizens only.**

Applications are kept in strict confidence. Send resume and salary requirement to Personnel Manager.

**PAUL ROSENBERG ASSOCIATES**
Consulting Physicists
*Established 1945*
100 Stevens Ave.
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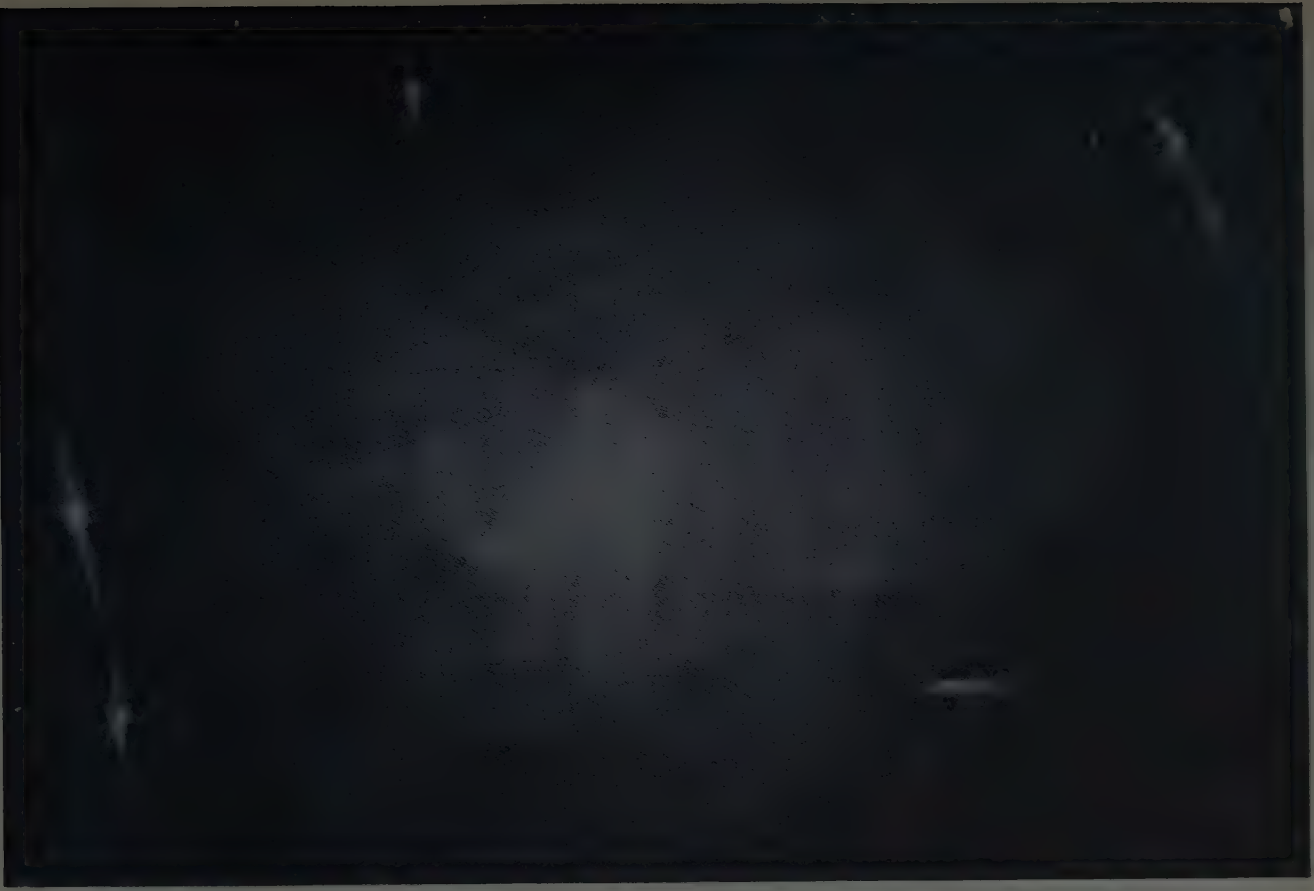


"FORCES OF NATURE," another in a collection of paintings by Simpson-Middleman, two talented artists who find in the natural sciences the subject matter for their contemporary expressions. Courtesy John Heller Gallery, Inc.

# Conquest of space

Boeing has geared its facilities, research and manpower resources to meet the complex technological requirements of the space age. The Systems Management Office, for example, has responsibility for the over-all management as well as the technical research and development activities in advanced flight technology, electro-magnetics and support systems leading to operational space weapon systems.

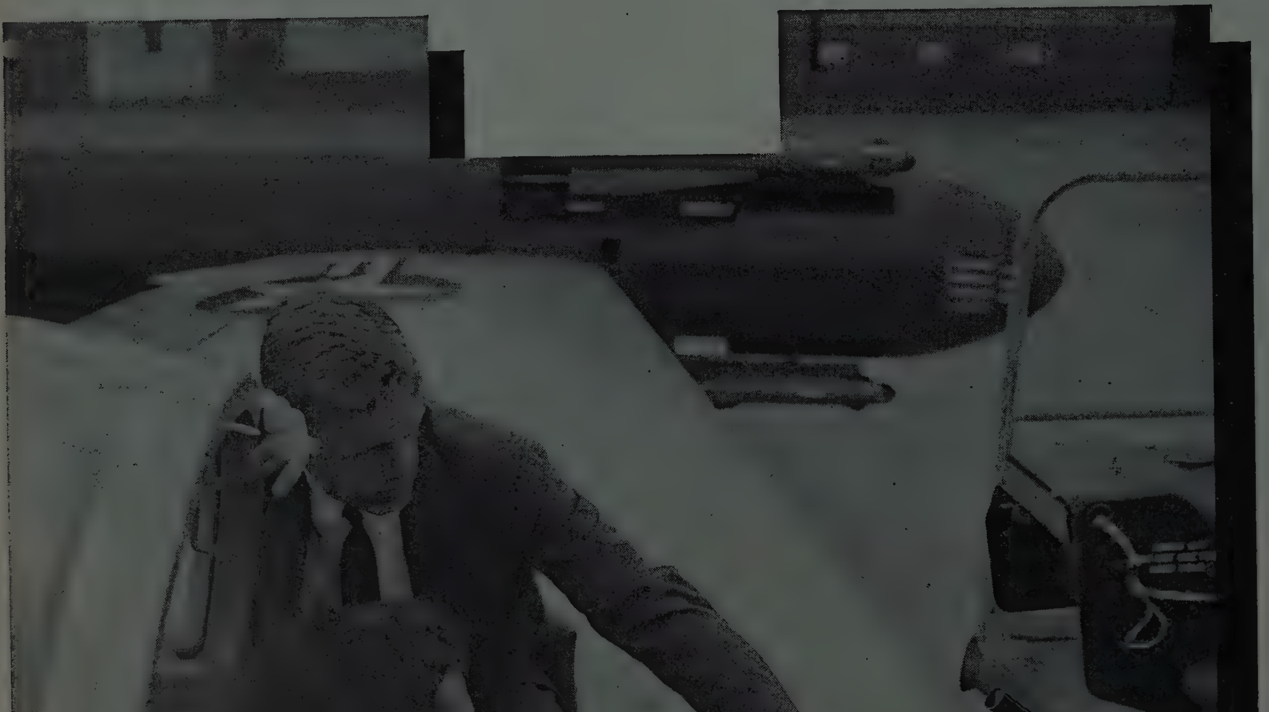
The Boeing Scientific Research Laboratories have been established to develop new, fundamental knowledge at the frontiers of science. They provide the environment of scientific freedom necessary to the attainment of this objective. Areas of investigation include, but are not limited to, hypersonics, energy conversion, solid state physics, magneto-hydrodynamics, nuclear and plasma physics, advanced propulsion systems, and the effects of high temperatures on structures and materials.

Boeing engineers and scientists are currently at work on an Air Force assignment for Phase I development of Dyna-Soar, a manned space vehicle which will orbit at speeds approaching 18,000 miles an hour and be capable of re-entry and normal landing.

Dyna-Soar and other advanced projects at Boeing offer exceptional space-age opportunities to engineers and scientists of all categories. Drop a note now to Mr. Stanley M. Little, Department G-80, Boeing Airplane Company, Seattle 24, Washington.

BOEING

THE LONG ARM OF



# THE LABORATORY

He takes Laboratory designed electronic systems and evaluates them where they actually prove themselves. He makes this equipment produce everything that was designed into it. His title: Hughes Field Engineer.

Responsible for the modification and maintenance of complex Electronics Armament Systems and Guided Missiles, he keeps in the forefront of the newest electronics developments. Working with complete integrated systems, the Hughes Field Engineer learns how each component works toward the working, fighting total.

This highly respected professional engineer forms a critical link in a strong engineering chain. As an extension of the Hughes Research & Development Laboratories, it is his job to recommend modifications in the basic designs. At the same time, he maintains liaison with the manufacturing groups, making sure that the highest standards of reliability have been built into the system.

The chain of Research, Development, Manufacturing and Field Evaluation is also evident in other Hughes activities. The commercial products activity performs all these functions in the areas of electron tubes, semiconductor devices, and industrial systems and controls. The Ground Systems Division performs all phases on protective radar systems.

This attention to the highest standards of engineering, combined with the diversity and wide scope of activity, makes Hughes an ideal firm for the engineer or physicist interested in career advancement.

*An immediate need now exists for engineers in the following areas:*

- Microwave Tubes
- Engineering Writing
- Semiconductors
- Field Engineering
- Computer Engineering
- Radar
- Communications
- Circuit Design
- Microwaves
- Systems Analysis

*Write, briefly outlining your experience, to Mr. Phil N. Scheid, Hughes General Offices, Bldg. 6-P-1, Culver City, California.*

**Molten Ladle** of silicon is watched during first step in the precise manufacture of Hughes semiconductors. Constant innovations in Research, Development and Manufacture have positioned Hughes Products as a commercial electronics leader.

**Electronic Scanning Radar** systems, a radically new concept in radar beam positioning, is currently being developed and manufactured by the Hughes Ground Systems Division.

*the West's leader in advanced electronics*

HUGHES

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HUGHES AIRCRAFT COMPANY
*Culver City, El Segundo,*
*Fullerton and Los Angeles, California*
*Tucson, Arizona*

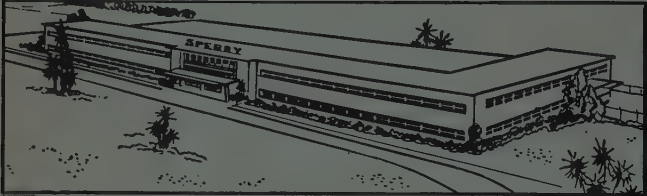
# ENGINEERS • DESIGNERS

The newly formed

## Sperry Microwave Electronics Company

*Division of Sperry Rand Corp.*

offers engineering growth opportunity plus stability



In Clearwater Florida

### Research, Development, Product & Product Design Work In Microwave Physics, Advanced Radar And Guided Missile Instrumentation

Sperry's leadership in the development of new concepts in microwave and electronic instrumentation and systems is well known to industry. These developments are important in precision navigation on the sea and in the air; control of many types of missiles; search systems for early-warning radar fences, countermeasures, and many other microwave and electronics projects both military and commercial. This new facility follows in the tradition of Sperry "firsts" which date back to the first gyro compass in 1910 and the first guided missile in 1915.

Qualified personnel joining Sperry here, not only share the opportunities for growth and advancement inherent in a brand-new unit, but also enjoy the security and stability of association with a parent corporation which employs 85,000 men and women in over 70 different plants.

A limited number of select openings exist for engineers qualified to accept unusual professional challenges. Remuneration is commensurate with experience and background. Experience in any of the fields below is required.

**INSTRUMENTATION** — Test equipment development, new measurement techniques, lab. instruments.

**ELECTRONICS** — Transistor circuits for military applications; pulse generation and handling techniques; printed circuits.

**COMPUTER TECHNIQUES** — Digital system logic & equipment synthesis; data handling & conversion.

**PRODUCT ENGINEERS** — Minimum of 2 years experience in engineering manufacturing coordination; knowledge of development engineering and shop processes; B.S. degree or equivalent in electrical or mechanical engineering.

**FERRITES AND SOLID STATE PHYSICS** — Isolators, duplexers, amplifiers and other component designs; material studies, broadband, low frequency and high power applications.

**MICROWAVE CIRCUITS** — Waveguide, coaxial and strip transmission line devices, broadbanding techniques, millimeter techniques.

**ANTENNAS** — Microwave optics & antenna theory; modern feed, reflector & novel lens designs; search, tracking & communications applications.

**MECHANICAL ENGINEERING** — Mechanisms, microwave component fabrication techniques, antenna drives and stabilization, equipment packaging.

**DESIGNERS** — Mechanical or electrical-mechanical experience.

*For further information, please contact employment supervisor.*

SPERRY

**Microwave Electronics Co.**
*Division of Sperry Rand Corp.*
**CLEARWATER, FLORIDA**

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*(Continued from page 128A)*

### SENIOR ELECTRONIC ENGINEERS

Experienced engineers to design and develop components and systems. Advanced degrees preferred. Positions are with the Seminole Division of Airpax Products Company. Products are of highest quality; management is young and aggressive; engineering is thoughtful and advanced. The division occupies a new building in Fort Lauderdale, Florida, with ideal living conditions. If you can make a positive contribution to this type of company and wish to live and work in this kind of atmosphere send resume to Personnel Director, The Airpax Products Co., P.O. Box 8488, Fort Lauderdale, Florida.

### SEMICONDUCTOR RESEARCH

Applied Research Scientist with background in semiconductor or related solid state field to investigate new semiconductor phenomena and new device principles. Send resume to Mr. A. G. Grasberg, Professional Employment Dept. PE-3, RCA Laboratories, Princeton, New Jersey.

### ELECTRONIC ENGINEER

For design and development work with high energy accelerators used in nuclear physics research program. Includes power electronics, pulsed circuits, vacuum systems and magnetic design. Qualifications: degree in electrical engineering or engineering physics, 2 to 5 years experience. Months' vacation, good conditions and benefits, competitive salary. Send resume of personal history, education, experience and references to Mr. J. J. Cochrane, Physics Research Lab. University of Illinois, Champaign, Illinois.

### RECEIVER-AMPLIFIER DESIGN ENGINEER

Engineering experience in the design and packaging of RF and IF Amplifiers, VHF and UHF Receivers (tube and transistor) desirable but not essential. Company now in its fifth year of operation and is located in the heart of the San Francisco Bay area. Competitive salary and company participation benefits. Send resume to R S Electronics Corp. 435 Portage Ave. Palo Alto, Calif.

### INSTRUMENTATION ENGINEER

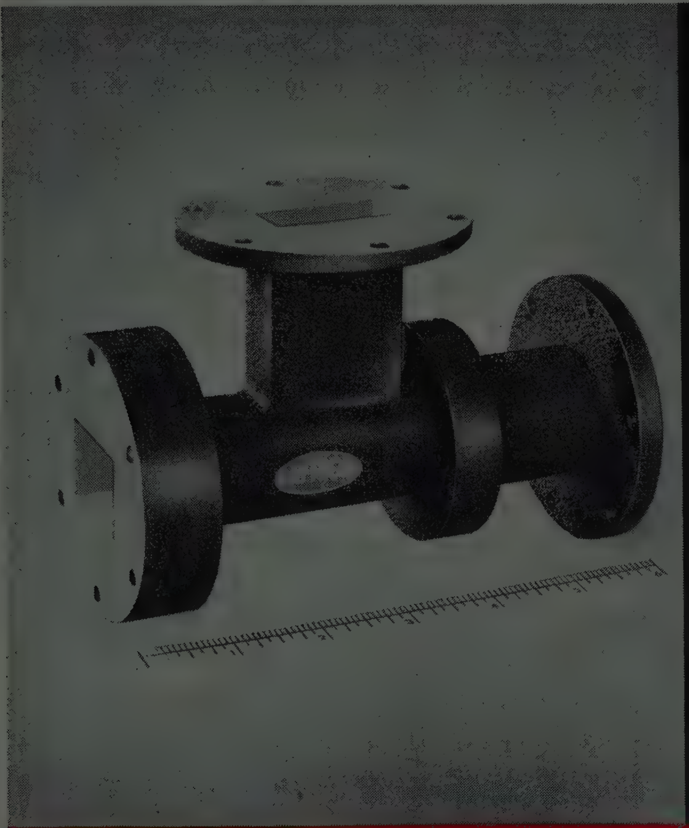
Opening for a graduate engineer with 5 to 10 years experience in commercial design of circuits for instrumentation use. Masters degree preferred. Experience should include pulse circuit, video amplifier and D-C amplifier designs. Specialists in any of these considered. Eastern location. In reply, please state education, experience, age and salary requirements. All replies in strict confidence. Box 1082.

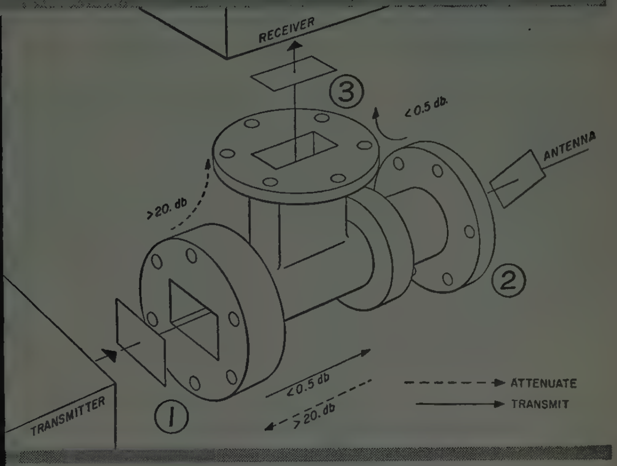
### TECHNICIAN

Technician as assistant in electronics services shop maintained in connection with University of Arkansas research program. Salary in the range of $3600 for 12 months with 2 weeks vacation. Address application or inquiry to Virgil W. Adkisson, Dean, Graduate School, University of Arkansas, Fayetteville, Arkansas.

*(Continued on page 134A)*

## *Recent Raytheon achievements in Microwave*





**THE MICROWAVE CIRCULATOR.** Typical of recent Raytheon developments in advanced microwave equipment and components is the microwave ferrite circulator recently developed by Raytheon's Special Microwave Device Group. **HOW IT WORKS:** in the diagram above, transmitted signals enter arm (1) vertically polarized. They are then rotated 45° from the vertical in a ferrite Faraday rotator with a longitudinal field applied by a small cylindrical permanent magnet. They flow out of the circulator at the antenna arm (2) which is set at the same 45° angle. Received signals fed into the antenna arm are rotated an additional 45° by the ferrite Faraday rotator and can only leave through the receiver arm (3).

## To the man who is looking for
## FRONTIER PROJECTS IN ELECTRONICS:

As an engineer or scientist who wants to accomplish more in 1958, you naturally want to be where new things are happening.

Whatever your specialized background and interests, chances are you'll find a current Raytheon project that offers exceptional opportunity for you to put your scientific skill and creative imagination to work.

Raytheon's constant expansion during 1958 covers advanced activities in:

**COMMUNICATIONS (Commercial and Military)**—scatter, microwave relay, multiplex, mobile transistorized equipment.

**COUNTERMEASURES**—radar countermeasures equipment, advanced study projects.

**RADAR (Pulse and CW Systems)**—search, fire control, bombing, navigation and guidance, air-traffic control, weather and marine, military and commercial.

**MARINE EQUIPMENT**—submarine, ship and airborne sonar, depth sounders, direction finders, radars.

**GUIDED MISSILES**—prime contracts:
Navy Sparrow III (air-to-air)
Army Hawk (ground-to-air)

**MICROWAVE TUBES**—"Amplitrons," magnetrons, klystrons, traveling wave tubes, storage tubes, backward wave devices.

**SEMICONDUCTORS**—devices, materials and techniques; silicon and germanium.

• • •

For interview and prompt helpful counsel, please write to
E. H. Herlin, Professional Personnel Section
P.O. Box 237, Brighton Station, Boston 35, Mass.

*Excellence in Electronics*

RAYTHEON

**RAYTHEON MANUFACTURING COMPANY**

*To the talented engineer and scientist*

APL OFFERS GREATER FREEDOM OF ACTIVITY

APL has responsibility for the *technical direction* of much of the guided missile program of the Navy Bureau of Ordnance. As a result staff members participate in assignments of challenging scope that range from basic research to prototype testing of weapons and weapons systems.

A high degree of freedom of action enables APL staff members to give free rein to their talents and ideas. Thus, professional advancement and opportunities to accept program responsibility come rapidly. Promotion is rapid, too, because of our policy of placing professional technical men at all levels of supervision.

APL's past accomplishments include: the first ramjet engine, the Aerobee high altitude rocket, the supersonic Terrier, Tartar, and Talos missiles. Presently the Laboratory is engaged in solving complex and advanced problems leading to future weapons and weapons systems vital to the national security. Interested engineers and physicists are invited to address inquiries to:

Professional Staff Appointments

The Johns Hopkins University
Applied Physics Laboratory

8603 Georgia Avenue, Silver Spring, Maryland

## Positions Open

*(Continued from page 132A)*

### ELECTRONIC CIRCUIT DESIGN ENGINEERS

Electronic Circuit Design Engineers—Several years experience and graduate training desirable (but not required) for challenging circuit design problems. Ability to work in small, outstanding group on varied high caliber design projects e.g. computer techniques application, data accumulation and reduction, pulse amplifier and discriminator design. Phillips Petroleum Company, Atomic Energy Div., P.O. Box 1259-C.T. Idaho Falls, Idaho.

### ELECTRONIC SUPPORT EQUIPMENT DESIGNERS

To determine system test and maintenance philosophy; analyze and coordinate the test requirements of radar, servo and computer type equipment; supervise the design of associated circuits. Requires programming and switching concept experience. Assist in establishing technical discussions for proposals and bid requests. Write Emerson Electric Mfg. Company, 8100 W. Florissant, St. Louis 21, Missouri.

---

## Positions Wanted

### By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

---

### ELECTRICAL ENGINEER

M.I.T. graduate Electrical Engineer with sales and engineering experience. Wants lines to represent in the New England area. Please write Box 1058 W.

### INSTRUMENTATION SALES

21 years experience in all phases of electronic instrumentation. This includes engineering, sales, management and production. Interested in position in sales management, application engineering or general management. Age 39, married, 2 children. Will relocate. Box 1059 W.

*(Continued on page 136A)*

solid
footing?

To a man floating weightless around Space Station C, these are perhaps meaningless words—but *solid footing* is highly important to most of us who live and work on the surface of the earth.

Autonetics has established a solid footing in inertial guidance through 12 years of successful development and production of airborne and ocean-going systems, as well as systems for space applications.

The healthy growth of the Autonetics Guidance Engineering department—based on a number of highly diversified contracts—has created new senior-level positions in the fields of electro-mechanical component development and system analysis.

Well qualified, experienced men will find solid footing in this permanent, progressive, and successful organization—plus the chance to create and to grow in one of today's most challenging fields.

But time's a-wasting. *Now* is the time to find out what the future holds for *you* at Autonetics.

Please send your resume to Mr. G. K. Benning, Manager, Employment Services, 9150 E. Imperial Highway, Downey, California.

NERVE CENTER OF THE NEW INDUSTRIAL ERA **Autonetics**
A DIVISION OF NORTH AMERICAN AVIATION, INC.

*Announcing . . .*

Career Opportunities for

**MICROWAVE SCIENTISTS**

at Westinghouse

Electronic Tube Division

**An accelerated growth in microwave activity at Westinghouse has created outstanding opportunities for experienced senior Engineers and Scientists.**

**Westinghouse has made notable advances in the development of new microwave tubes and devices: PLASMA CONTROL MICROWAVE DEVICES, MASERS, PARAMETRIC AMPLIFIERS, TRAVELING WAVE TUBES.**

**We are looking for senior Engineers and Scientists with Ph.D. or M.S. degrees, (or high level experience in microwave devices) for our rapidly expanding program.**

**Openings are available in the following classifications:**

- **MANAGERIAL POSITIONS**
- **TOP RESEARCH POSITIONS**

***At these two locations:***

**ELMIRA, N.Y.**

Our Microwave R & D Laboratory at Elmira, N.Y. is located in the Finger Lakes Region, 45 minutes from Cornell University where Westinghouse engineers are working toward advanced degrees. Opportunities to work in unexplored fields with highest type of professional and academic association providing a fine environment for individual achievement.

**BALTIMORE, MD.**

The Microwave Tube Section of our Applied Research Department in Baltimore, Md., provides a stimulating environment for microwave engineers working closely with systems engineers of Westinghouse defense divisions on space age problems. Opportunity for qualified candidates to work for advanced degrees at Johns Hopkins and University of Maryland under the Westinghouse supported Graduate Study program.

We'll Be In . . .

**WASHINGTON, D.C.**

**Oct. 30, 31, Nov. 1**

**Mr. ROSS KILGORE, Manager of Applied Research, will be at the Shoreham Hotel to talk with those interested in career opportunities. Westinghouse Headquarters personnel will also be available for discussion.**

*For Interviews . . .*

**PHONE Mr. Kacala, ADams 4-0701, Shoreham Hotel**

**Write or send resume to Mr. William Kacala, Technical Recruiting, P.O. Box 284, Dept. M-1B, Elmira, N.Y., or phone collect ELmira 9-3611.**

**Westinghouse**

ELECTRONIC TUBE DIVISION ELMIRA, NEW YORK

## Positions Wanted

### By Armed Forces Veterans

*(Continued from page 134A)*

### ELECTRONIC ENGINEER

Bachelor of Science in mathematics, Tulane University 1957. Desires career position in electronics. Veteran with military electronics experience. Age 27; single. Remuneration of secondary importance if working conditions are interesting. Special interest in electronic computers. Box 1060 W.

### ADVERTISING MANAGER

12 years heavy experience in sales promotion of consumer and industrial electrical and electronic products. Knows selling and marketing research. Fully versed in all phases of publicity, public relations, sales promotion, and working with advertising agencies. Radio amateur hobby extending back to 1932. 3 years engineering education with degree in marketing and management. Box 1061 W.

### ELECTRONIC TECHNICIAN

10 years aircraft radio and electronics experience on commercial air lines. 1½ years digital computer experience. Past 5 years spent doing instruction and part-time supervision. Hold 1st class radiotelephone license. Box 1062 W.

### ELECTRONIC ENGINEER

Liaison Engineer engaged in contractual and technical administration of multi-million dollar subcontract desires position in project administration or liaison. BBA, MBA. 8 years diversified electronic experience including test equipment design and systems engineering. Schooled in military electronics. Box 1070 W.

### ENGINEER

7 years transformer experience including design, production, test and the writing of specifications for transformers and their materials. Special experience in EPOXY resin embedment and in close tolerance reactor work. Box 1071 W.

### ELECTRONICS EXECUTIVE

Graduate with 12 years experience in communications and controls. Leader. Desires challenge. Box 1072 W.

### ELECTRONIC ENGINEER

Age 26. BSEE 1954; MSEE 1956. TBII, KME, HAM License. Lt. (j.g.) USNR. 3 years with missiles and radar. Release from active duty Feb. 1, 1959. Desires position where graduate work may be done, double option, communications and industrial electronics-analog computers. Box 1075 W.

### TECHNICAL WRITER

Submarine veteran with college background in E.E. and journalism. Presently program director and FM engineer for small radio station. Successful free-lance writer. Desires position where ability to creatively translate engineers' notes into English will be used. Age 25, Married. Box 1076 W.

### TELECOMMUNICATIONS ENGINEER

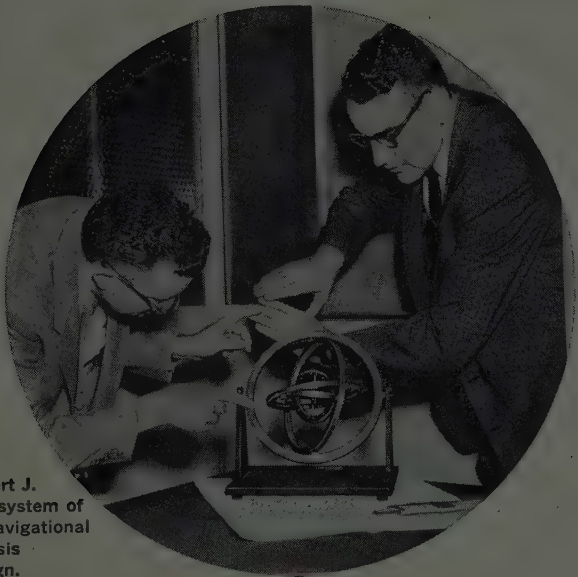
B.Sc. (Eng.) 1st class Honors London University, telecommunications. Age 33. 7 years experi-

*(Continued on page 138A)*

Circuit Development
Group Leader Ralph Wolcott
(left) considers future changes
in computer output unit for
bombing—navigational systems.

*Ground-floor opportunities in*

NTEGRATED BOMBING-RADAR-NAVIGATIONAL SYSTEMS *at* IBM



oject Engineer Robert J.
ntwell (left) uses a system of
nbals to describe navigational
oblems in the analysis
a new system design.

Staff Engineer William Howard (center) reviews gearing accuracy requirements of test equipment with electronic circuit designers.

The design and development of advanced airborne computers at IBM Owego offer an unusual professional opportunity to engineers and scientists today. At this IBM Military Products facility you now have a chance to work on completely integrated bombing-radar-navigational systems. And it's just like joining a new company — the ground-floor opportunities you will find at IBM Owego. In addition, you have all the advantages . . . all the security . . . of IBM.

Challenging assignments now open

- Airborne analog and digital computer systems
- Inertial Guidance
- Test equipment developme
- Radar circuits and systems
- Transistor circuit design

Qualifications

**B.S. or M.S. degree** in electrical or mechanical engineering, physics, or mathematics, and

**Proven ability** to assume a high degree of technical responsibility in your sphere of interest.

**FOR DETAILS,** just write, outlining background and interests, to:

**Mr. P. E. Strohm, Dept. 645W**
**Military Products Division**
**International Business Machines Corp.**
**Owego, New York**

**IBM is a recognized leader** in the rapidly expanding electronic computer field. Its products are used for both commercial and military applications. Continuous growth affords excellent advancement opportunities. The "small-group" approach assures recognition of individual merit. Company benefits set standards for industry, and salaries are commensurate with your abilities and experience.

IBM MILITARY PRODUCTS

DATA PROCESSING
ELECTRIC TYPEWRITERS
MILITARY PRODUCTS

SPECIAL ENG'G. PRODUCTS
SUPPLIES
TIME EQUIPMENT

Plants and laboratories: Endicott, Kingston, Owego, Poughkeeps
Yorktown, N. Y.; Lexington, Ky.; Rochester, Minn.; San Jose, Ca

CHEMICAL AND PETROLEUM ENGINEERS
ELECTRONIC ENGINEERS
PHYSICISTS
COMPUTER ENGINEERS

DIGITAL COMPUTERS
FOR PROCESS CONTROL

The Thompson-Ramo-Wooldridge Products Company is seeking engineers and scientists to participate in the design and application of digital computer systems for the control of manufacturing processes, especially in the petroleum and chemical industries. Staff members work on a variety of processes, studying various control problems and synthesizing control systems which take into consideration the complex factors governing optimum process operation. Applicants holding advanced degrees in engineering, physics, or chemistry are preferred.

*Those interested are invited to write to the*
Director of Engineering,
THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY
POST OFFICE BOX 45067, AIRPORT STATION, LOS ANGELES 45, CALIFORNIA

STANFORD RESEARCH INSTITUTE

*Has Responsible Professional Opportunities in Applied Electronic Engineering Fields for*

ELECTRONIC ENGINEERS
PHYSICISTS
MATHEMATICIANS

SRI

*Opportunities in the Following Research Activities:*

PROPAGATION
CONTROL SYSTEMS
COMPUTER DEVELOPMENT
MICROWAVE COMPONENTS
SYSTEMS ANALYSIS
ANTENNAS
COMMUNICATION TECHNIQUES
MATHEMATICAL RESEARCH
DISPLAY DEVICES

The continuing growth of activities at SRI offers excellent opportunities for qualified personnel on the MS and PhD levels with at least 5 years of experience in Electronic Engineering or Applied Physics.

Projects are varied and professionally challenging, offering unique opportunities to develop personal competence and broad experience.

Stimulating association, good research facilities and responsible assignments, coupled with living and working in one of the most desirable areas of the San Francisco Bay Area, compliment an atmosphere conducive to professional growth and development.

*Advance study opportunities available in the area.*

*Write to...*
PROFESSIONAL EMPLOYMENT MANAGER
STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

## Positions Wanted

## By Armed Forces Veterans

*(Continued from page 136A)*

ence of design and construction of every type of electronic equipment. Recent research on semiconductors. A.M.I.E.E., Member IRE. Several publications on circuits. Available in U.S. later this year. Box 1077 W.

### SENIOR ELECTRONIC TECHNICIAN

Experienced Senior Electronic Technician. Presently Chief Technician. 13 years electronics background; amateur license; 3 years as Radar Theory Instructor; data handling background; digital techniques; magnetic perforated tape handlers. Leadership abilities in supervisory capacities proven by minimum of last 5 years. Desires challenge with opportunity. Box 1078 W.

### ENGINEER—PILOT

BS.E.E., Princeton University. Age 31, married, 2 children. Desires position combining engineering talents and Beechcraft Pilot qualifications in engineering administration, application, liaison, sales or project supervision. 7 years diversified experience encompassing project engineering, flight test and instrumentation, electromechanical and electro-hydraulic design, application and sales engineering. Present responsibilities include hydraulics, radar drives and control systems, antenna selection and RF feed assemblies. Considerable experience in cost estimating and preparation of technical proposals. Prefer New Jersey or other eastern location. Box 1079 W.

### ELECTRONIC TECHNICIAN

Graduate RCA Institutes. Varied background in machine accounting. Currently maintaining large digital computer airlines reservation system. Audio and industrial electronics interest. Evening E.E. student. Hold 1st class radiotelephone license. Box 1081 W.

## NEWS
## New Products

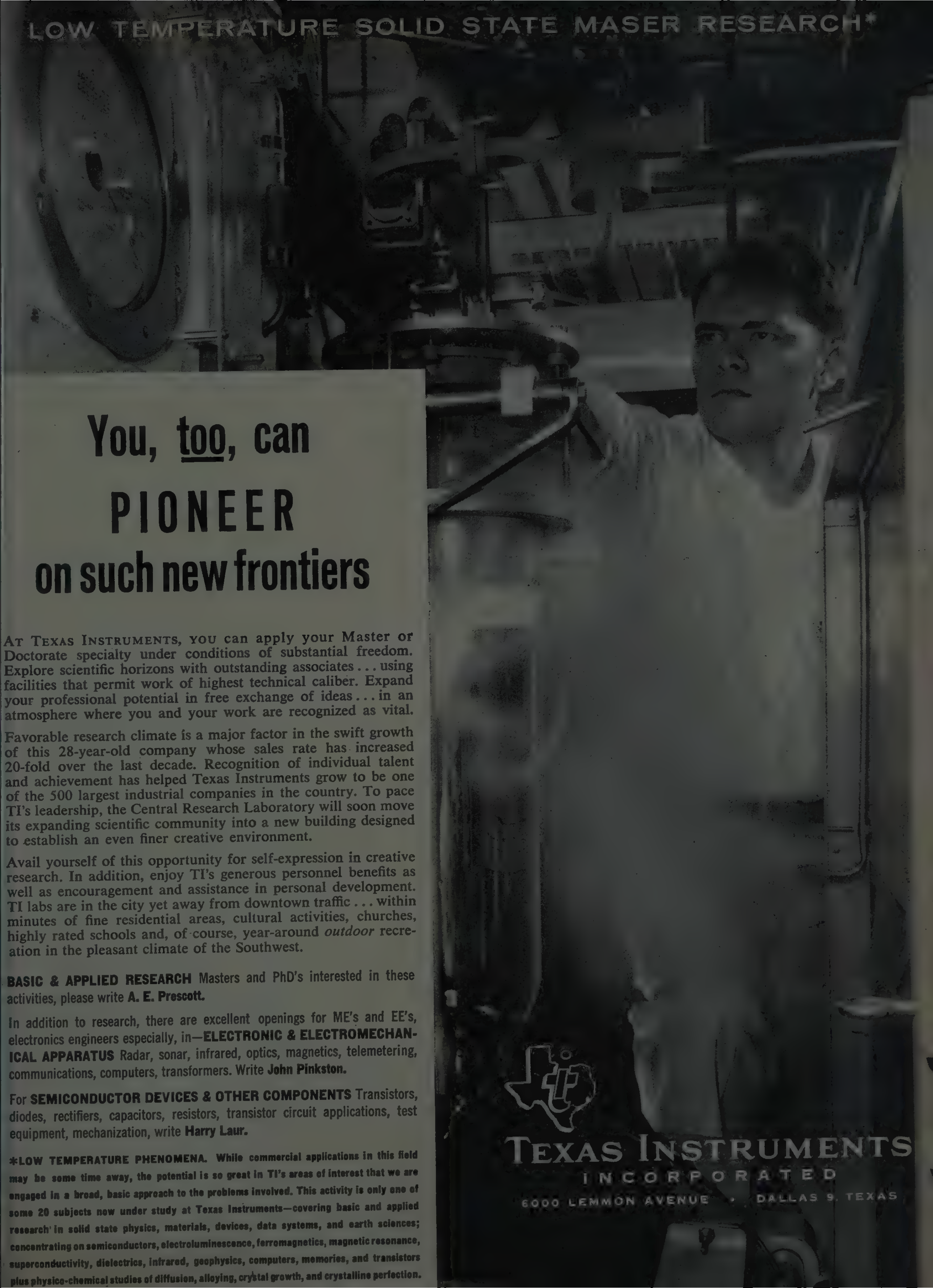
*(Continued from page 122A)*

## CBS-Hytron Consolidates Facilities

Consolidation of its mechanical and electronic equipment design, development and production facilities by **CBS-Hytron** is nearing completion according to M. C. Callahan, vice president and general manager—receiving tube operations. The firm's mechanical and electronic equipment departments, formerly in Salem, Danvers and Newburyport, Massachusetts, are now centralized at its latest modern plant in Newburyport.

Callahan said James Christofferson, manager, mechanical equipment development, is charged with supervision of all activities of the mechanical engineering group and the experimental and production machine shops. Joseph Giuffrida, manager, electronic equipment development, heads the electronic equipment design, development and construction groups, he said.

*(Continued on page 140A)*



LOW TEMPERATURE SOLID STATE MASER RESEARCH*

# You, too, can PIONEER on such new frontiers

AT TEXAS INSTRUMENTS, YOU can apply your Master or Doctorate specialty under conditions of substantial freedom. Explore scientific horizons with outstanding associates . . . using facilities that permit work of highest technical caliber. Expand your professional potential in free exchange of ideas . . . in an atmosphere where you and your work are recognized as vital.

Favorable research climate is a major factor in the swift growth of this 28-year-old company whose sales rate has increased 20-fold over the last decade. Recognition of individual talent and achievement has helped Texas Instruments grow to be one of the 500 largest industrial companies in the country. To pace TI's leadership, the Central Research Laboratory will soon move its expanding scientific community into a new building designed to establish an even finer creative environment.

Avail yourself of this opportunity for self-expression in creative research. In addition, enjoy TI's generous personnel benefits as well as encouragement and assistance in personal development. TI labs are in the city yet away from downtown traffic . . . within minutes of fine residential areas, cultural activities, churches, highly rated schools and, of course, year-around *outdoor* recreation in the pleasant climate of the Southwest.

**BASIC & APPLIED RESEARCH** Masters and PhD's interested in these activities, please write **A. E. Prescott.**

In addition to research, there are excellent openings for ME's and EE's, electronics engineers especially, in—**ELECTRONIC & ELECTROMECHANICAL APPARATUS** Radar, sonar, infrared, optics, magnetics, telemetering, communications, computers, transformers. Write **John Pinkston.**

For **SEMICONDUCTOR DEVICES & OTHER COMPONENTS** Transistors, diodes, rectifiers, capacitors, resistors, transistor circuit applications, test equipment, mechanization, write **Harry Laur.**

***LOW TEMPERATURE PHENOMENA. While commercial applications in this field may be some time away, the potential is so great in TI's areas of interest that we are engaged in a broad, basic approach to the problems involved. This activity is only one of some 20 subjects now under study at Texas Instruments—covering basic and applied research in solid state physics, materials, devices, data systems, and earth sciences; concentrating on semiconductors, electroluminescence, ferromagnetics, magnetic resonance, superconductivity, dielectrics, infrared, geophysics, computers, memories, and transistors plus physico-chemical studies of diffusion, alloying, crystal growth, and crystalline perfection.**

TEXAS INSTRUMENTS
INCORPORATED
6000 LEMMON AVENUE • DALLAS 9, TEXAS

Daring!

AVCO
Crosley

*Engineers at CROSLEY are embarked on a number of electronics' programs that stagger the imagination. Horizons are expanded — new concepts are probed . . . CROSLEY engineers are daring to do the impossible! Why don't you and CROSLEY join as "Partners in Opportunity".*

**HERE ARE FIELDS OF CURRENT ACTIVITY:**

1. *Ground Radar*
2. *Airborne Defense Systems*
3. *Antenna and Micro-Wave Equipment*
4. *Computer and Analytical Services* (DESIGN AND DEVELOPMENT) (PROGRAMMING & APPLICATION)
5. *Communications* (AIRBORNE TRANSMITTERS AND RECEIVERS)
6. *Airborne Fire Control*
7. *Servo-Mechanisms*
8. *Transistorized Equipment*
9. *Guided Missiles*
10. *Infrared Research*

*Write us for complete details. We'll send you literature and we'll tell you about the advantages of family living in Cincinnati—"Queen City of the West, Closest to the Heart of America". There are numerous company benefits and you will be paid generous relocation expenses.*

*Send your resume to:* **FRANK PLASHA, PERSONNEL MANAGER, DIVISION HEADQUARTERS DEPT. 37**

**AVCO** MANUFACTURING CORPORATION
CROSLEY DIVISION
1329 ARLINGTON STREET, CINCINNATI 25, OHIO

CHALLENGING OPPORTUNITIES IN RESEARCH AND DEVELOPMENT

ELECTRONIC ENGINEERS
SYSTEMS ENGINEERS

Design of electronic instrumentation for underwater ordnance. Analytical and experimental treatment of scientific research problems in the fields of hydrodynamics, acoustics, electronics, network theory, servomechanisms, mechanics, information theory and noise analysis including analogue and digital computations.

THE PENNSYLVANIA STATE UNIVERSITY
ORDNANCE RESEARCH LABORATORY
University Park, Pennsylvania

☐ Opportunities for Graduate Study
☐ Faculty Appointments for Qualified Applicants
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SEND RESUME TO: ARNOLD ADDISON, PERSONNEL DIRECTOR

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 138A)*

## Oil-Filled Potentiometer Data

Three liquid-filled potentiometers now produced by **Helipot Div., Beckman Instruments, Inc.,** Fullerton, Calif., supply subject matter for Data Sheet 1482, a seven-page technical summary just published by the firm.

All working parts of the new potentiometers are sealed in a bath of oil which effectively cushions the unit against shock and vibration, protects it against environmental changes, increases dielectric strength, and flushes away wear particles that can reduce life and cause noise. Fully described in the data sheet are a ten-turn $1\frac{1}{16}$ inch diameter model and three-turn and ten-turn 2 inch diameter models.

Photographs, power input charts, dimentional drawings, electrical and mechanical specifications, standard coil data and a list of readily available modifications tell the complete product story.

Copies of Data Sheet 1483 may be obtained from Helipot Technical Information Service, Fullerton, Calif.

## Mallory Appoints Slater and Larrabee

Ira M. "Duke" Slater, formerly Sales Manager of the P. R. Mallory & Co., Inc., vibrator Division, Du Quoin, Illinois, has been appointed Manager, Sales Engineering of the division. Fred H. Larrabee, Jr. becomes the division's Sales Manager.

Slater

Larrabee

Larrabee, a native of Kansas City, Mo., was vice president of the Fred H. Larrabee Company, manufacturers representatives in Kansas City and St. Louis, before joining Mallory in June. He served with the Signal Corps Section, Fifth Army, during World War II.

He was graduated from the University of Kansas in 1948. In 1951 he was recalled to active military duty and served as a company commander in Germany.

Slater, a veteran of more than 30 years in the radio and electronics field, has held sales and engineering positions with Mallory since 1931. Previous to his present appointment, he was Vibrator Engineer, Chief Vibrator Engineer, Sales Correspondent, Application Engineer, Sales

*(Continued on page 142A)*

# ENGINEERS

*Our service covers the nation —at no cost to you.*

## Salaries to $18,000

Some positions for non-citizens

**PARTIAL LISTING**

MANAGEMENT ENGINEER $18,000
Micro wave transmitter or receiver design, should know systems study

OPTICAL LEADER $17,000
Supervise optical R & D group in systems for infra red

FIRE CONTROL LEADER $16,500
R & D analogue computers, applying to complex fire control computers, some bkgd in magnetic amplifiers & diode shaping network

SECTION MANAGER $16,000
10 to 15 yrs exp in supervision radar products; must have aggressive nature

PROJECT LEADER $16,000
Optical and infra red systems, know radiometers, photo sensitive detectors, should have administrative ability

ELECTRONIC ENGINEERS to $16,000
Monopulse, monocon & scanned radiation systems, microwave systems

TECHNICAL STAFF $15,000
Fundamental research in new mathematical routine for digital computers

RESEARCH ENGINEER $15,000
PhD in EE required: must have excellent bkgd in field of radar and counter measures; job entails pure research and is not administrative

SECTION MANAGER to $14,000
Communications: must have exp. in supervision of engineering projects

DIGITAL ENGINEER to $12,500
Design of electronic data processing technique, electronic transistor design commercial application

ELECTRONIC ENGINEER $12,500
Good bkgd in panoramic receivers & counter measure systems, Connecticut

MICRO WAVE $12,000
Design & development of microwave systems, antennas and plumbing

PACKAGING ENGINEER to $12,000
Packaging of electronic circuits, familiar with military specs

PHYSICIST to $12,000
Design & development of accoustic products, headsets, mike, etc.

SONAR ENGINEER to $12,000
Bu Air or Bu Ship exp. good electronic design bkgd; New England area

PROJECT ENGINEER to $11,000
Expd in radio frequency range, know crystal filters: California

ELECTRONIC ENGINEER to $11,000
Airborne communications, UHF & VHF transmitter design

AUDIO ENGINEER to $10,500
Expd in design of audio equipment such as amps, tuners, etc.

RELIABILITY ENGINEER $9600
Select components and specify electrical devices; need 1 man with EE and 1 with ME. New Engl.

ELECTRONIC ENGINEER $9000
3 to 4 years exp R & D of circuits, bkgd in pulse circuits, transistors and radar, N Y C area

*Send 3 copies of your resume in confidence to:*

Harry L. Brisk—Member IRE
**ACCREDITED PERSONNEL SERVICE**
12 So. 12th St., Philadelphia 7, Pa.

**ENGINEERS & SCIENTISTS:**

# Why opportunities are *better* at Melpar

*IN BOSTON AND WASHINGTON, D.C. AREAS*

**Growth and Diversification:** Since 1945 Melpar has experienced a steady growth, and today we are engaged in a number of highly advanced weapon systems programs as well as 110 different electronic research, development, and production projects. Our continuous expansion coupled with our emphasis on diversification assure uninterrupted career advancement for staff members.

**Professional Gratification:** At Melpar you can choose to grow in a specialized sphere of activity or, as a member of a project team, you can broaden your experience by participating in all phases of a project from initial concept on through to prototype completion.

**Environment:** Our modern and well-equipped laboratories are located in choice suburban areas near Washington, D. C. and Boston, Massachusetts. These locales were selected because of their proximity to superior educational, cultural and recreational facilities. Fine housing in all price ranges is readily available.

**Positions are available for men with experience in the following fields:** Systems evaluation • Digital computer circuitry • Analog computer instrumentation • Data processing • Microwave design • Pulse circuitry Operations analysis • Advanced mathematics • Electromechanical design • Receiver design • Subminiaturization • Electronic production engineering.

For detailed information about openings, write to:
Technical Personnel Representative

**MELPAR** *Incorporated*
A Subsidiary of Westinghouse Air Brake Company
**3158 Arlington Boulevard, Falls Church, Virginia**
*10 miles from Washington, D.C.*

ELECTRONICS ENGINEERS
and PHYSICISTS

Aeronutronic is expanding military and commercial programs involving the most advanced research, development, experimentation and prototype production at plants in Glendale and at modern, new facilities overlooking the Pacific Ocean at Newport Beach, California.

Career opportunities are open for scientists and engineers of high calibre in the fields of space technology, range instrumentation, missiles electronics, automatic controls, and display systems. Advanced degree and three to five years' experience in telemetry, radio propagation, atmospheric physics, servomechanisms, electronic and/or mechanical design, or plasma physics desirable. U.S. citizenship necessary. Qualified applicants are invited to send resume to Mr. L. R. Stapel.

AERONUTRONIC SYSTEMS, INC.
*a subsidiary of Ford Motor Company*
1234 Air Way, Bldg. 29, Glendale, California · CHapman 5-6651

MICROWAVE
TUBE
ENGINEERS

An expanding program of vital military and commercial developments has created new openings for qualified engineers and scientists interested in microwave tube research, development, design and application.

If you are interested in growth opportunities and have experience in the field of microwave beam devices such as klystrons and traveling wave tubes, microwave components and related technology, you are invited to write Professional Personnel Director, Division 48

GENERAL ELECTRIC

MICROWAVE LABORATORY
601 CALIFORNIA AVENUE
PALO ALTO • CALIFORNIA

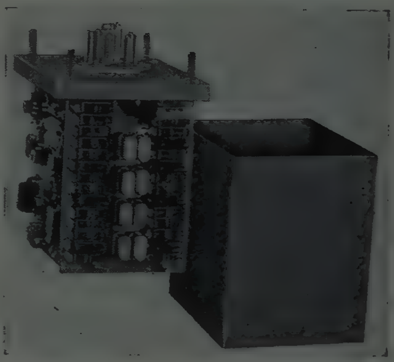
**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.**

*(Continued from page 140A)*

Engineer, Sales Section Head and Sales Manager.

Slater, a native of Lebanon, Indiana and a graduate of Wabash College, is a Senior Member of the Institute of Radio Engineers, a Fellow Member of the Radio Club of America, and Associate Member of the Aircraft Owners & Pilots Association, and a member of the Indianapolis Engineers Club. During his college years he was a member of the American Radio Relay League.

## Audio-Frequency Standard

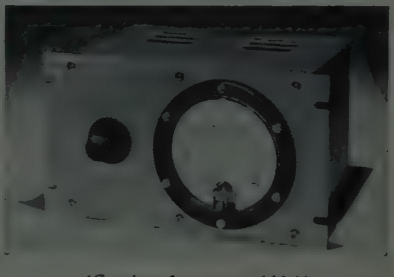


Stability at high shock and vibration is a feature of the new TCO/300-OC AF standard, manufactured by **Reeves-Hoffman Div., of Dynamics Corp. of America,** Carlisle, Pa. This transistorized crystal oscillator with oven control can withstand shock up to 100 g's or vibration from 0 to 2,000 cps at 10 g's. Frequency range is 400 to 2,000 cps. Frequency stability is ±0.002 per cent over a temperature range from −55 to +85°C. Output is of the square-wave type. The unit will meet applicable portions of MIL-E-5272A.

This oscillator weighs 11 ounces, including its hermetically sealed metal holder and four $\frac{6}{32}$-inch studs for mounting.

## Electronic AC Voltmeter

Difficult-to-measure voltages may be read accurately with a new militarized ac electronic voltmeter, developed in the half relay-rack style by **Metronix, Inc.,** Chesterland, Ohio.



*(Continued on page 144A)*

## IMPORTANT DEVELOPMENTS AT JPL

# PIONEERS IN EARTH-SPACE COMMUNICATIONS

The exploration of outer space will take a new step forward with the completion of the new giant radio antenna being installed by JPL near Barstow, California. This huge "dish," 85 ft. in diameter, will enable the Laboratory scientists to probe still farther into space problems.

Information thus obtained and combined with lessons still being learned from the successful Army "Explorer" satellites, will provide invaluable basic data for the development of communication systems to serve space exploration programs. Long range communication will begin as a one-way link from space to earth, developing later into tracking and communicating with lunar vehicles at far greater ranges.

This activity will be part of a great research and development program to be operated jointly by JPL and the United States Army Missile Command.

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are invited to join the Lincoln Laboratory scientists and engineers whose ideas have contributed to new concepts in the field of electronic air defense.

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## NEWS New Products

(Continued from page 142A)

With its circuitry completely isolated from the front panel and dust cover, the multi-range Model 480 voltmeter will measure "floating" of "off-ground" voltages, such as those across a servomechanism's windings, plate-to-plate readings in push-pull amplifiers, and similar applications.

Overall construction of the unit, which uses a panel $5\frac{1}{4}$ inches high and $9\frac{1}{2}$ inches wide, complies with MIL-T-945A requirements. The meter meets the MIL-M-10304A specifications and all other components conform to the appropriate military specifications. Printed circuit technique is used throughout.

An average reading device calibrated in RMS for a sine wave signal, Model 480 has a high input impedance of 10 megohms, 20 $\mu\mu$f. This makes it particularly suitable for measurements at audio and supersonic frequencies.

Frequency response of this voltmeter is from 20 cps to 100 kc. Accuracy is ±2 per cent up to 50 kc, ±3 per cent thereafter.

Full-scale voltage ranges, easily selected with a switch on the panel, begin with 10 millivolts and progress in 10 db steps to 300 volts. Power requirements are 115 volts, 50 to 400 cps, single phase, 10 watts.

(Continued on page 146A)

**CONTROL SYSTEMS ENGINEERS**

An experienced engineer is required for work in our systems development group. He should possess an above average electronics background and from two to six years of experience in servomechanisms, infra-red, and missile guidance development. Advanced degree, preferable, but will consider outstanding personnel with a B.S. degree.

This is a challenging opportunity for qualified personnel to fully utilize their creative ability on highly diversified research assignments while enjoying stimulating staff associations and receiving an excellent salary and liberal employee benefits including tuition free graduate study.

Please send a complete resume to:

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of Illinois Institute of Technology
10 W. 35th St. Chicago 16, Ill.

ELECTRONIC ENGINEERS OR PHYSICISTS

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*This select group requires 1 or 2 specialists in each of the following areas:*

Automatic Test Equipment
Undersea Warfare (airborne and submarine sonar systems)
Advanced Communications Systems
Digital Computer Systems (airborne navigation and missile guidance)

*For additional information, please address your inquiry, with an indication of your background, to Mr. Fred E. Lee, Manager of Technical Personnel.*

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**Electrical Systems Analysis and Design,** Mission and Traffic Control, Fire Control, Bombing Systems, Electronics Systems Integration, Flight Controls, Ground Support Equipment, Airborne and Electronic Test Equipment.

**Applied Research** in Radome Development, Antenna Development, Infrared, and Acoustics.

Please write to: Mr. B. K. Stevenson, Engineering Personnel, North American Aviation, Los Angeles 45, California.

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**Circuit Designers**—Design digital computer transistorized circuits (commercial application systems). Decision-making concerning reliability, cost and producibility of components and systems. Make application of magnetics in design of digital computer high-speed memories. Advanced degree preferred.

**Circuit and Logical Designers**—Similar activities to circuit designer plus evaluation and de-bugging arithmetical and control areas of computer systems. Advanced degree preferred.

**Systems Engineers**—Formulate comprehensive technical systems requirements for data-processing systems.

### ELECTRICAL ENGINEERS

Design relay (electro-magnetic) circuits in data-automation systems for retail and bank applications.

### MECHANICAL ENGINEERS

Design of intricate mechanisms associated with development of data-processing systems. (*Positions also available, Adding Machine Division, Ithaca, New York.*)

**SEND RÉSUMÉ TO:** Mr. K. I. Ross,
Professional Personnel Section J,
The National Cash Register Company
Dayton 9, Ohio.

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The Electronics Division of Curtiss-Wright Corporation, located at Carlstadt, New Jersey, has immediate openings for the following:

## RADAR PROJECT ENGINEERS

BSEE with a minimum of 10 years experience in the design and development of unique circuitry for simulation and utilization of radar signals and returns from stationary and moving targets. Knowledge of military specifications, pulse and sweep circuitry techniques, video amplifiers, servo-mechanisms and analog computers required. Must have ability to supervise engineers and technicians and to successfully follow a project from conception to completion, including breadboarding and prototype phases, and test and calibration of final system.

Additional openings at senior and intermediate levels.

## DIGITAL COMPUTER ENGINEERS

For design and development of large scale special purpose real time computer systems and equipment. Broad knowledge of digital computer applications plus 3 to 6 years of current systems and logical design experience required.

## SERVO SYSTEMS ENGINEERS

Junior, intermediate and senior positions open in the design of servo systems using standard components and modifications of existing systems to meet new requirements. BSEE required.

Send complete resume giving details of experience, education and salary requirements to:

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**Mgr., Engineering Recruitment,**
**Dept. ED 1,**
**Curtiss-Wright Corporation,**
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All replies confidential

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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 144A)*

## Modified Linear Amplifier

A new modified linear amplifier, Vantron "300-A", has been introduced by the **Electronics Div., Van Norman Industries, Inc.,** 186 Granite St., Manchester, N. H.

The Vantron "300-A" incorporates many unusual features and has been submitted to rigorous testing. Compact, easy to operate, fully shielded, it is capable of high power SSB, CW and AM operation, and is ideally suited for single side-band operation. The amplifier features a minimum of tuning adjustments, requires 15 watts maximum driving power, and has a self-contained, heavy-duty power supply. The "300-A" has no "plug-in" coils, tunes continuously from 3 to 35 mc. Field tests have proven it to be of low harmonic output, free from parasitics, and with excellent stability throughout its frequency range.

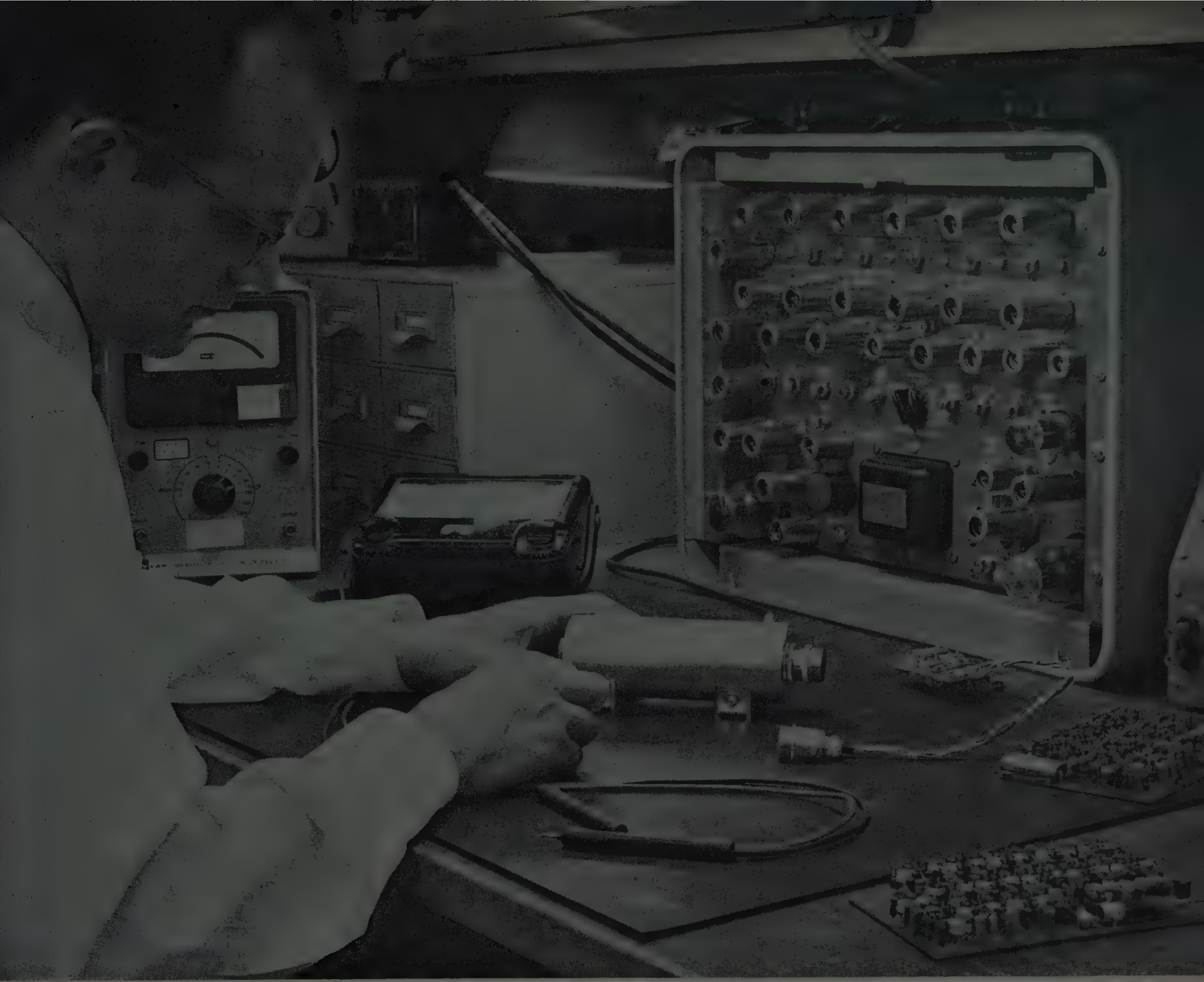
Only two adjustments for plate tuning and antenna coupling are required. Power input is 150 watts p.e.p. on SSB, 240 watts on CW, 100 watts input on AM. Thoroughly shielded and tvi filtered, it is finished in attractive sturdy steel. The unit, which measures $8\frac{1}{4}\times8\frac{1}{4}\times9\frac{1}{2}$ inches, weighs 18 pounds.

Only readily replaceable tubes are used throughout. Plate current metering is provided for easy tuning and loading, as well as safe operation. The "300-A" will easily drive a grounded grid amplifier with 1000 watts p.e.p. input, and it matches 50 to 75 ohm antennas. The tube complement consists of two EL-34/6CA7 units and a GZ-34 rectifier.

## Miniature Twin-T Filters

Miniature Twin-T Filters suitable for mounting on printed-circuit boards are offered by **T. T. Electronics, Inc.,** P. O. Box 180, Culver City, Calif. These precision-tuned networks are encapsulated in an epoxy resin for maximum stability under extreme environmental conditions. The attenuation at the null frequency is guaranteed to be 50 db or more. **Mylar®** capacitors and deposited carbon resistors

*(Continued on page 148A)*



*A MISSILE AND TELEVISION INDUSTRY FIRST. Lockheed-developed, miniaturized TV cameras, designed for both government and commercial use. Only 6 inches long and 2¼ inches in diameter, tiny cameras extend man's vision into the unexplored. Unmanned lunar probes to the far side of the moon; lunar landings; monitoring interiors of manned spacecraft and remote TV coverage of on-the-spot happenings on a scope never before possible are some of the uses foreseen for the cameras.*

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Responsible positions for high-level, experienced personnel are available in research and development, in our project organizations, and in manufacturing.

Particular areas of interest include microwave, telemetry, radar, guidance, solid state, reliability, data processing, instrumentation, servomechanisms, flight controls, circuit design and systems analysis, test, infrared, and optics.

If you hold a degree and are experienced in one of the above fields, we invite your inquiry. Please write to Research and Development Staff, Dept. 3011, 962 W. El Camino Real, Sunnyvale 12, California.

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## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 146A)*

are used for temperature stability. Standard null frequencies are 30, 60, 120, 400 and 800 cps. Impedance levels range from 53 to 850 k ohms. The filter circuit proportions used are those for the sharpest null characteristic. Filters designed to other frequencies and conforming to specified printed board layouts are available on special order.

Special features of these miniature filters are small size and low cost. The cylindrical package is $\frac{13}{16}$ inch in diameter and $1\frac{1}{2}$ inches long. Three No. 18 solid-copper tinned leads are used for mounting. Spacing between adjacent leads is 0.4 inch. Flat, rectangular packages with leads at specified points are available on special order.

For literature or additional data contact the firm.

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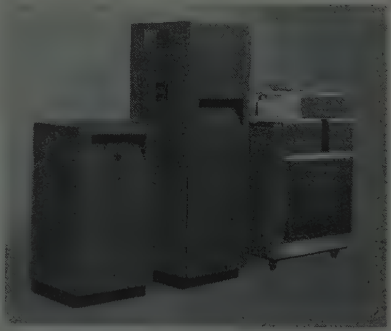
### Data Transmission System

**Collins Radio Co.,** 2700 W. Olive, Burbank, Claif., announced it is marketing a new high speed data transmission system, the TE-206 (left), which when used with the new Collins 768G-1 Kinecard Converter (middle) and IBM 523 card reader/punch unit (right) reproduces and transmits punch card information at a rate of 100 cards per minute. The system is capable of operating in full or half duplex and simplex modes.



The TE-206 unit conveys information at voice frequencies over wire-line, cable, carrier or microwave telephone facilities. The new Collins equipment is completely transistorized to reduce heat and keep maintenance to a minimum. New signalling techniques provide superior signal-to-

*(Continued on page 150A)*

*Announcing*

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**for**

**IMAGE TUBE ENGINEERS & PHYSICISTS**

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**Our laboratory in Elmira, N.Y. is located in the Finger Lakes Region, 45 minutes from Cornell University, where Westinghouse engineers are working toward advanced degrees. Professional and academic associations provide a fine environment for individual achievement.**

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**Oct. 30, 31, Nov. 1**

Mr. DEWEY KNOWLES, Manager of Image Tubes, will be at the Shoreham Hotel to talk with those interested in career opportunities at Westinghouse. Headquarters personnel will also be available for discussion.

***For Interviews***

**PHONE Mr. Kacala,**

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Write or send resume to Mr. William Kacala, Technical Recruiting, P.O. Box 284, Dept. M-1C, Elmira, N.Y. or phone collect ELmira 9-3611.

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BS required and advanced degrees desirable. Experienced applicants and recent graduates should write to:

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Combat surveillance is a systematic, round-the-clock watch over a battle area under all weather conditions. To the Indian Scout of the past it was what he could physically see and hear — with information sent back to the battle party by smoke signals. To the military commander of the future, combat surveillance will be complicated by the vastness of the battle area and by the diversity, mobility and destructive power of atomic-age forces and weapons. He must have new systems of surveillance involving every facet of electronics — radar, infrared, sonic, television and many others. C.A.L. is proud to have been selected as scientific advisor to the Army Signal Corps in this area. As such the Laboratory will evaluate present programs, review practices and tactics, and devise and recommend new systems and supporting research programs to the Army Combat Surveillance Agency.

This task is but one of the Laboratory's highly stimulating electronic projects that have included Radar Cross Section Studies, Automatic Carrier Controlled Approach, TACAN, Data Link and Traffic Control Computer, Automatic Landing System with Deck Motion Predictor, and LACROSSE, a Surface-to-Surface Guided Missile. If you seek broader vistas in an atmosphere attuned to major scientific explorations in the field of electronics, write today for our fact-filled, illustrated 68-page report entitled "A Decade of Research." The coupon will bring you a free copy.

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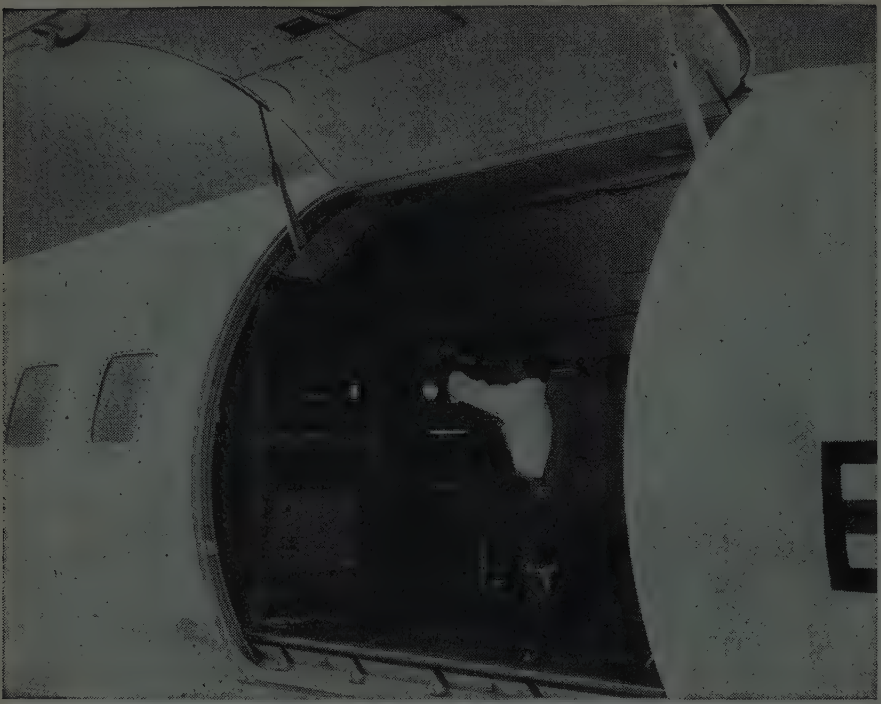

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**Newly formed project groups solve complex airborne radar problems**

Engineers like the project-type organization at Raytheon's Maynard Laboratory. It gives them maximum diversification in their work on the most advanced radar navigational and control problems of the day.

At Maynard, you'll find projects involving many areas of aircraft navigation and guidance systems . . . doppler navigation, velocity check systems, night-fighter operations systems, flight-control systems, altimeters. There is also interesting new work on countermeasures equipment.

Career opportunities for men at all levels now exist in the following areas:

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For complete details on engineering positions in any of Maynard's project groups, please write John J. Oliver, P.O. Box 87P, Raytheon Maynard Laboratory, Maynard, Mass.

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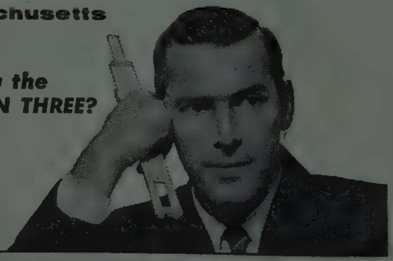


RAYTHEON
MAYNARD LABORATORY
Excellence in Electronics

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 148A)*

noise performance and efficient spectrum utilization.

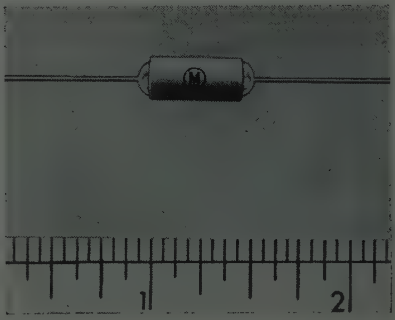
The card reader supplies information to the Kinecard Converter which translates the information and applies it to the eight channels in the TE-206 transmit terminal. At the receive terminal, information from the eight channels in the TE-206 is stored in the Kinecard Converter until sufficient information is available to supply to the card punch unit.

Errors in transmission are detected by odd and even parity checks on each card. Cards in error are identified for re-transmission by offset stacking.

Full information on the new system can be obtained from Collins Radio.

## Voltage Sensitive Capacitors

**Mucon Corp.**, 9 St. Francis St., Newark 5, N. J., now makes available a new group of voltage sensitive ceramic capacitors with capacitance as low as 60 $\mu\mu$f for those applications where the previous minimum capacitance of 100 $\mu\mu$f was not low enough. Their capacitance may be decreased as much as 60 per cent by applying dc potential up to 200 volts.



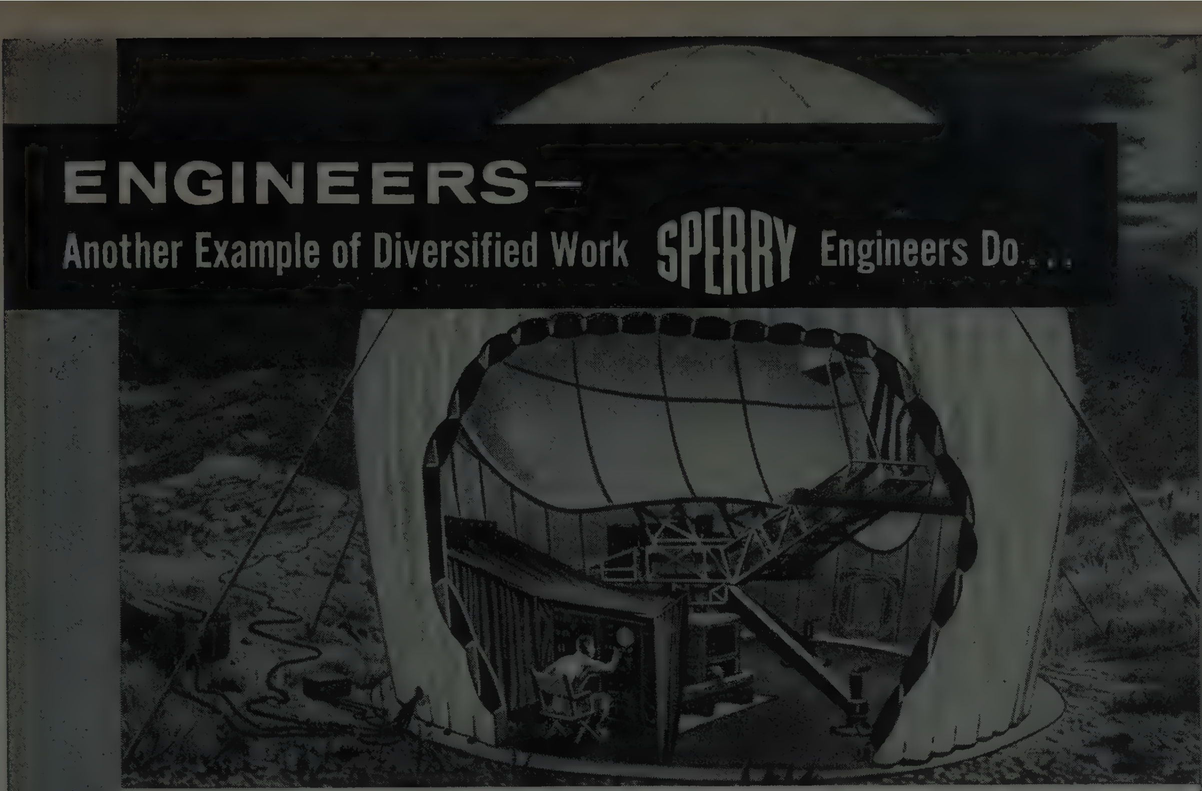
These types LVSR and LVSE are housed in a steatite tube approximately $\frac{7}{32}$ inch diameter and approximately $\frac{9}{16}$ inch long with soldered in #26 gauge leads. Being temperature sensitive, type LVSR has maximum sensitivity at room temperature, while type LVSE has voltage sensitivity at approximately 70°C.

There are unlimited applications in the fields of tuning and frequency control, harmonic generation, frequency modulation, dielectric amplifiers, etc.

## Strain Gage Calibrator

A new, self-balancing instrument which is used for calibration or measurement of strain gages, strain gage type transducers and other resistance instruments is now offered by **Datran Electronics**, 1836 Rosecrans Ave., Manhattan Beach, Calif. Known as the Datran RBI (Resistance Bridge Indicator) Model A-202, this in-

*(Continued on page 152A)*



# ENGINEERS—

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As fast on the move as a fighting Marine is the new "TEW" (tactical early warning) radar system being developed by Sperry for the Marine Corps. Only one-fourth the size and weight of conventional radars, TEW is easily carried to battle areas by helicopter, cargo plane, truck or amphibious vehicle. Within two hours, an 18-man crew can erect the TEW system and place it in operation.

With its very long range and portable construction, TEW provides the Marines with the means to extend the nation's defense perimeter and insure added protection for key installations and outposts.

***If you're interested,<br>not in an engineering job,<br>but in an engineering CAREER,<br>check Sperry—***

Sperry Gyroscope also stands for steady growth. Not just for the company—but for its engineers. Sperry engineers are career engineers, working on projects—like TEW—that are creative, interesting, important. They stay, and grow, with us. That's why over 2,600 Sperry employees are 15-year men. And—today we're expanding, diversifying more than ever. If engineering is your life's work—check Sperry.

***Openings in many specializations including the following:***

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RADAR TRANSMITTERS • INFRARED SYSTEMS
PULSE CIRCUITS • TIMING CIRCUITS
ELECTRONIC PACKAGING
TRANSISTOR CIRCUITS
*For Pulse & Video Applications*
MICROWAVE ANTENNA DESIGN

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***J. W. Dwyer***
***Employment Manager***

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***Saturday Interviews***
***8 A.M.-1 P.M.***
***Arranged by Appointment***

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**GYROSCOPE COMPANY**
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RADAR SYSTEMS ANALYSIS
ELECTRONIC INSTRUMENTATION

**Receive excellent salary, and liberal benefits including generous relocation allowance, tuition free graduate study and an exceptional vacation program. Send complete resume to:**

**A. J. Paneral**
**ARMOUR RESEARCH FOUNDATION**
**of Illinois Institute of Technology**
**10 West 35th St. Chicago 16, Ill.**

*(Continued from page 150A)*

strument reads actual values such as psi, microinches per inch, foot pounds, etc., and automatically handles both positive and negative input signals to indicate values from −1000 to +1000.

The front panel controls permit the following settings for strain gage problems: gage factor, number of active legs, full or half bridge, zero balance, amplifier gain control, positive or negative load, transducer voltage level, and electrical zero.

In addition, a calibration selector switch enables an operator to shunt any one of the 4 possible bridge legs with a choice of 5 precision calibration resistors which are built into the instrument and observe the digital reading to determine calibration.

This new instrument, which eliminates special set-up time and minimizes operator reading errors, can be used in many applications including wind tunnels, structural test labs, instrument labs, aircraft and missile test stands and production departments to provide greater accuracy of readings and reduce the cost of measurements.

## Scintillation Well Counter

A scintillation well counter of advanced design (Model SWC-1), being introduced by **Nuclear-Electronics Corp.**, 2925 N. Broad St., Philadelphia 32, Pa., incorporates a maximum amount of shielding in a minimum package size and weight. Two inches of lead shielding is provided in a sectionalized unit with a 7 inch diameter by $12\frac{1}{4}$ inches high, weighing 95 lbs. The sectionalized design permits easy moving of the instruments from one location to another. The scintillation probe comes equipped with a 2×2 inch NaI crystal, has

*(Continued on page 154A)*

# BROAD SPECTRUM

# OF ADVANCED PROJECTS AT STROMBERG-CARLSON

## *Electronics Arm of General Dynamics Corporation in Rochester, New York*

The many areas in which research, development and design groups work include radar, navigation, microwave communications, air traffic control, sonar, automatic test equipment, guided missile electronics, nuclear instrumentation, telecommunications, electro-acoustics, and Hi-fi equipment.

Recently Stromberg-Carlson was appointed Systems Manager and Prime Contractor for an important new USAF passive reconnaissance system.

You join two professional communities when you come to Stromberg-Carlson—the company, and the City of Rochester, which has the largest percentage of professional people for a city of its size (500,000) in the nation. And in many other ways Rochester is an ideal spot for an engineer or scientist to live and raise a family...noted for its cultural advantages; advanced study opportunities at U. of Rochester with its famed Eastman School of Music and Symphony; unrivaled park and school systems; modern hospitals. And Rochester, gateway to the Finger Lakes, is in New York's famous upstate vacationland, near Niagara Falls, Thousand Islands and Adirondack Mountains.

*Immediate openings for:*

### RESEARCH & ADVANCED DEVELOPMENT

**LABORATORY MANAGER**—Radio Communications. To direct R&D involving information theory, modulation techniques, propagation phenomena, microwave techniques etc.

**SENIOR MATHEMATICIAN**—PhD or outstanding MS in Math, Physics, or EE. Specialist in information theory applied to communications and data systems.

**PHYSICISTS or EE's**—experienced in communications research involving microwave technology, solid state circuitry and mathematical investigations.

### ELECTRONICS ENGINEERING

**SENIOR STAFF ENGINEERS**—heavy experience in one of the following areas, to become a recognized authority:

1. Automatic test equipment.
2. Undersea warfare (airborne and submarine sonar systems).
3. Digital computer systems (airborne navigation and missile guidance).
4. Advanced communications systems.

**PRINCIPAL ENGINEER**—to develop and investigate new ideas in automatic control, including digital computer problems.

**SECTION HEAD**—broad experience in electronic circuit design and development, data handling, automatic test equipment, communications or navigation.

**SENIOR EE's, PHYSICISTS or EE's**—for major phases in development of such projects as:

1. transistorized nuclear reactor instrumentation.
2. transistorized industrial process control equipment.
3. advanced navigation techniques including TACAN and NAVTAC.
4. advanced automatic test equipment.
5. airborne and underwater Sonar.
6. countermeasures.
7. advanced communications systems.
8. transistorized digital machine tool controls.

### ELECTRONIC SYSTEMS

**SECTION HEAD**—PhD or MS in EE or Physics. To supervise and act as consultant and liaison specialist in systems design work—both theoretical and equipment—in broad communications projects.

**SECTION HEAD**—to supervise integration of antennas (emphasis on broadband ECM receiver types) into an ECM reconnaissance system.

**SENIOR ENGINEERS**—experience in systems theoretical design and/or equipment design. Requires knowledge of entire electromagnetic spectrum, working knowledge of propagation methods.

### TELECOMMUNICATIONS

**PRINCIPAL SCIENTIST**—to consult on semi-conductor problems. Requires knowledge of application of solid state devices in electronics engineering; theory of semi-conductors etc.

**SENIOR ENGINEERS**

1. for telephone network design including modern synthesis filters, delay equalizers, discriminator networks, loss and phase equalizers, transistor switching circuitry etc.
2. for R&D of electronic switching systems involving solid state devices and new relay switching circuits.

**EE's or Equivalent**

1. experienced in carrier engineering, knowledge of dial and manual telephone systems.
2. for systems engineering work required by telephone central office equipment.

*If you qualify for one of the positions listed above,*
*write immediately to Fred E. Lee, Manager of Technical Personnel.*

S·C

**STROMBERG-CARLSON**
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GD

ENGINEERS
and
SCIENTISTS
there's genuine opportunity at General Mills

The Mechanical Division of General Mills, Minneapolis, Minnesota, needs senior level staff personnel for creative design and development in the following fields:

**Advanced Digital Computer Systems Design**

**Advanced Digital Computer Circuit Development**

**Advanced Pulse and Video Circuit Development**

**Advanced Electromechanical Computer Development**

**Advanced Inertial Navigational System Development**

**Optical and Infra-Red Equipment Engineering**

**Test and Evaluation of Basic Electronic and Electromechanical Components**

**Aerodynamicists**

**Telemetry systems engineers**

Positions available for *purely technical* and for *technical*-supervisory work—job titles and salary provide *equal* opportunity for advancement in both.

Positions exist in Engineering Department which is engaged in advanced design and development of military weapons and reconnaissance systems, communications, controls, guidance, navigation, and special purpose digital computers. Work is mainly military, with some special commercial instrumentation and control.

If you have at least five years' experience in creative design or development—a good understanding of fundamentals and ability to apply them—learn more about the opportunity and long range security offered at General Mills. You'll like our people, our interesting, non-routine projects—and you'll like Minnesota, land of lakes and pine. In Minnesota everyone takes time to enjoy life.

***Write for more facts.***

MECHANICAL DIVISION General Mills

Personnel Department P 4
2003 E. Hennepin, Minneapolis 13, Minn.

## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 152A)*

a well for 1 inch diameter samples and includes a built-in preamplifier. When the shield plug is removed, the probe unit automatically elevates to the top of the shield for ease in sample changing. An additional tubular lead shield plug is provided for use with extra long sample holders.

### Ramey VP of Northrop Aircraft

Lt. Gen. Roger M. Ramey, USAF, Retired, has been elected a corporate vice president of **Northrop Aircraft, Inc.,** Beverly Hills, Calif., in charge of the company's District Offices, Northrop President Whitley C. Collins announced.

Ramey will supervise the activities of Northrop offices in Washington, D. C.; Dayton, Ohio; Omaha, Neb.; Ogden, Utah; Huntsville, Ala., and Colorado Springs, Colo. He will move to Washington from his present home in Fort Worth, Texas.

Ramey was previously associated with Northrop as a consultant to the company's Radioplane Division. He retired from the U. S. Air Force in January, 1957, following a distinguished military career.

*(Continued on page 156A)*

ELECTRONIC ENGINEERS . . .
MICROWAVE
JUNIORS AND SENIORS

IMMEDIATE OPENINGS IN NEW YORK CITY

Medium sized expanding electronics firm has several challenging openings for electronic engineers with microwave experience for our design & development dept. Microwave antenna, filters & stripline experience desirable.

These positions offer a maximum opportunity for creative development as well as the opportunity to build a substantial future.

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BROOKLYN 6, NEW YORK

ARE YOU A MICROWAVE ENGINEER?
If So . . .

The Government & Industrial Division of Magnavox is looking for an engineer with 5 years or more experience in antennas, mixers, and similar waveguide components, rotary joints, etc., to head up a small microwave group. The individual we are looking for should have a broad familiarity with microwave test methods and test equipment. He should also have some knowledge of microwave fabrication—both model shop and production—so that he is aware of design problems that may be created in the production areas.

If you are able to direct 3 or 4 people to begin with and are willing to work on hardware yourself, **why not forward your resume to:**

Mr. S. S. Schneider
Director of Engineering
**The Magnavox Company**
Fort Wayne, Indiana

Other Senior positions available for engineers with 3-10 years design experience in communications, navigation, and airborne radar equipment.

work in the fields of the future at NAA

TEST EQUIPMENT ENGINEERS

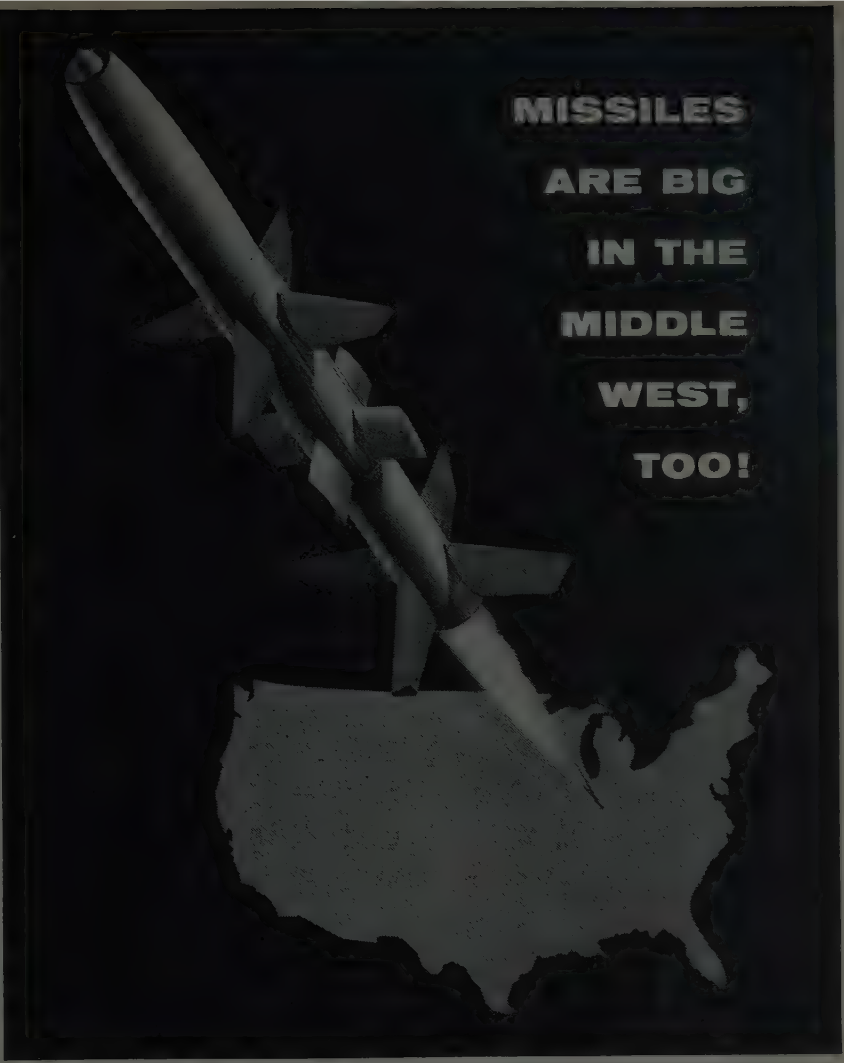
If you've been looking for an opportunity to explore new engineering territory, the positions now open in our electronics test equipment group may be right down your alley.

We need engineers to do research and development based on an entirely new electronics test equipment philosophy. Briefly, the job involves design of test equipment and analysis of electronics designs submitted by vendors and subcontractors. This is one phase of our work on advanced weapon systems B-70 and F-108.

A BSEE, plus experience, can qualify you.

For more information please write to: Mr. B. K. Stevenson, Engineering Personnel, North American Aviation, Inc., Los Angeles 15, Calif.

THE LOS ANGELES DIVISION OF
NORTH AMERICAN AVIATION, INC.



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If you have the qualifications, you can build yourself an enviable engineering career with Bendix—and enjoy living in one of America's fine residential and recreational areas.

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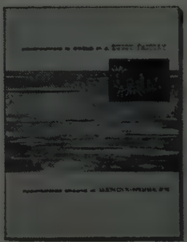
You'll enjoy a pleasant four-season climate, have excellent educational facilities available to you and your family, and have easy access to Chicago. Most of all, you'll find satisfaction in doing important work alongside men who are professional engineers. Mail the coupon today for a copy of "Opportunities Abound at Bendix Missiles".



**Bendix Products Division—Missiles**
402S So. Beiger St., Mishawaka, Ind.

Gentlemen: I would like more information concerning opportunities in guided missiles. Please send me the booklet "Opportunities Abound at Bendix Missiles."

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What the merger with United Aircraft means to an engineer joining Norden Laboratories today

- Increased Opportunities for Far-Ranging Exploratory Work in the fields where Norden has made so many contributions:
  missile & aircraft guidance, re-entry attitude control problems, radar and communications, inertial and stellar-inertial navigation, data-handling and navigation-stabilization systems, bomb director systems, and other specialized electronic areas.
- All the Long-Term Career Benefits and Unusual Growth Potential of association with one of the country's major leaders in the development of advanced aircraft propulsion systems.
- Plus the Professionally Rewarding Norden Laboratories Way of Working in small R&D groups...the invigorating contact with colleagues who know—and appreciate—each other's attainments ...the challenging diversity of assignments.

*Current opportunities exist at both White Plains, NY and Stamford, Connecticut locations for work on a number of advanced projects*

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*Design & Development openings in the following areas:*
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**STABILIZATION & NAVIGATION**
• COMPUTING SERVOS • SERVO AMPLIFIER DESIGN

**TELEVISION & PASSIVE DETECTION**
• TV DISPLAY CIRCUITRY • TV CAMERA CIRCUIT DESIGN
• TV TRANSISTOR CIRCUITRY

**QUALITY ASSURANCE**
• RELIABILITY ANALYSIS • STANDARDS • ENVIRONMENTAL TEST

**SYSTEMS**
• RADAR SYSTEMS

**ENGINEERING DESIGN**
• ELECTRONIC PACKAGING • MATERIALS

**DIGITAL**
• DIGITAL (SENIOR)—DESIGN: Logical, circuit, magnetic storage

TECHNICAL EMPLOYMENT MANAGER
NORDEN LABORATORIES
NORDEN DIVISION
UNITED AIRCRAFT CORPORATION
121 Westmoreland Avenue White Plains, New York

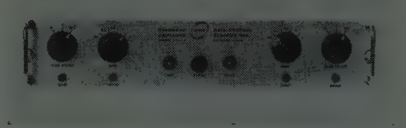
I am interested in obtaining further information on opportunities at Norden Laboratories.

Name____________________
Address____________________
City__________ Zone_____ State__________
Degree________________ Year__________

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 154A)*

## Recorder Amplifier



A new, two channel, power-output, recorder amplifier, Model GGA-2, to be used to drive high frequency galvanometers, has been announced by **Data-Control Systems, Inc.,** 39 Rose St., Danbury, Conn Designed specifically to amplify the output of the company's subcarrier discriminators for use in FM/FM telemetry systems, the recorder amplifier is useful in all applications requiring relatively large current outputs over a wide range of audio frequencies (0 to 25 kc).

The unit is dual-Channel, chopper-stabilized and is capable of delivering up to 200 ma at zero to ±10 volts, dc or peak ac, in each channel. The gain is adjustable from 0.1 to 2.0. Panel size is $3\frac{1}{2} \times 19$ inches.

## Keach Named Sales Rep for Dage TV

Appointment of Bernard C. Keach as Western regional manager for **Dage Television Division, Thompson Products, Inc.,** Michigan City, Ind., manufacturer of closed-circuit TV equipment, was announced today by James L. Lahey, General Manager.

Keach moves to Dage from the Electronic Division of Thompson Products, where he has acted as West Coast representative for the past 5 years.

Lahey said the appointment of Keach as a direct factory representative is designed to strengthen and improve sales and service of Dage products in the western region. Keach will maintain offices at 207 Hindry Ave., Inglewood, Calif.

A graduate of Newark College of Engineering, Keach is married and is the father of three children. He resides at 5517 Riviera Way, Torrance, Calif.

## Pressure Transducer Bulletin

Publication of a technical brochure on gauge, absolute and differential pressure measurements, is announced today by **Gulton Industries, Inc.,** 212 Durham Ave., Metuchen, N. J.

Entitled "Glennite Strain Gauge Pressure Transducers," the brochure describes

*(Continued on page 158A)*

## ELECTRONIC ENGINEERS PHYSICISTS

Senior Staff Positions are available for research and advanced development in areas of:

- Circuitry
- Antennas
- Sonics and Ultrasonics
- Radio Direction Finding
- Instrumentation
- Transducer Development
- Industrial Control

Positions offer creative challenge and opportunity for professional growth.

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**R. C. MAYS**
**Personnel Director**
**Southwest Research Institute**
**8500 Culebra Road**
**San Antonio, Texas**

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## ENGINEERS
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- World Famous Universities for ADVANCED STUDY
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Fabulous Southern California
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companies pay interview, relocation and agency expenses

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**at**

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- **Top salaries paid.**
- **All benefits included.**

**Work in small groups of engineers, where advancement is based soley on individual merit and ability.**

***Digital Techniques***

Design of storage devices, systems logic, computer circuitry, solid state data processing, analog to digital converters.

***Radar-Fire Control & Guidance***

Digital systems analysis, antenna design, RF & microwave components, beacons.

***Navigational Systems***

Pulse doppler design, display devices, servo mechanisms, analog computers.

***Communications Systems***

Frequency synthesizers, single side band transmitters and receivers. Telemetering.

*If unable to apply personally, send resume to*

**DAYSTROM INSTRUMENT**

Division of Daystrom Incorporated
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**System Analysis, Design and Test**
Radar
Navigation
Communications
Missile Guidance
Data Processing and Display

**Circuit Design, Development and Packaging**
Microwave
Antenna
R-F and I-F
Pulse and Video
Digital and Analog
Transistor
Servos

**Technical and Specification Writing**
**Printed and Etched Circuitry**

*Write:*
Mr. Kel Rowan
Western Military Electronics Center
Motorola, Inc., Dept. C-10
8201 E. McDowell Road
Phoenix, Arizona

***Engineering positions also available at Motorola, Inc. in Chicago, Illinois, and Riverside, California.***

**MOTOROLA, INC.**

**NEWS New Products**

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 156A)*

the performance, application, mechanical and electrical specifications, compatibility in installations and instructions for ordering the instruments. Also included are circuit diagrams, a typical installation and a basic explanation of the operation of the equipment.

Applications for the use of Glennite Pressure Transducers include aerodynamic loading, environmental pressure measurement and control systems, and the instruments can be used with galvanometer and tape recording systems, telemetry and analog-to-digital data handling systems.

The four-page, two-color illustrated brochure can be obtained by directing requests for Bulletin Series PSG-1 to the Sales Manager, Gulton Instrumentation Div.

### PNP Germanium Power Transistors

A new flexible line of PNP germanium power transistors has been announced by **CBS-Hytron, a Division of Columbia Broadcasting System, Inc.,** Danvers, Mass. which allows the customer to specify his

*(Continued on page 160A)*

**IF**

**You are:**

**an engineer, thinking of a job change* wondering about how to have the**

chance to consider the opportunities in many firms without spending the proverbial year and a day doing it,

would like to get a really good position with a leading firm—

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**An outstanding management consulting firm**

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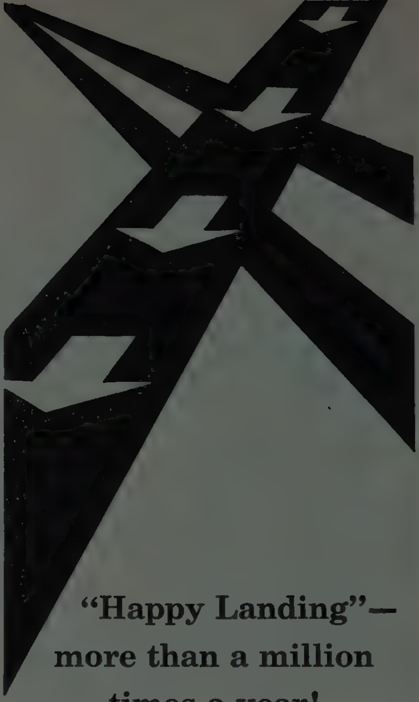

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EVERY 30 seconds, somewhere in the free world, an aircraft makes a touchdown with the aid of the ITT-developed "ILS"—instrument low-approach system—produced domestically by Federal Telephone and Radio Company, ITT's largest U.S. manufacturing unit.

This famed landing system is only one of many vital products made in Federal's million-square-foot plant. Federal also produces Tacan, Vortac, Data Link, missile guidance and command systems, automatic check-out and ground test equipment, data processing computers, countermeasures, direction finders, fire control and radar simulators, radio transmitters and receivers, ATC transponders, microwave equipment and other electronic and telecommunications systems for air navigation and military use.

Men of ambition and skill will find Federal's diversity a fertile field for challenging and rewarding opportunities...in country-like atmosphere ...only minutes away from the heart of New York City!

**For further information on opportunities at Federal—located in Clifton, New Jersey—write to ITT Technical Placement Office, 67 Broad Street, New York 4, N.Y.**

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*A Division of*

ITT

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## Man-Machine Relationships: A New Field for Scientists and Engineers

A new field for Operations Research Specialists, Engineers, Computer Programmers and Behavioral Scientists has arisen from System Development Corporation's work on relationship of men and machine systems.

It involves two major projects: 1 *creating and conducting large-scale training programs in present and planned air defense systems; and* 2 *operational computer programming for SAGE.*

Attaining the most effective interaction between men and machines is of prime importance. It requires intensive effort in an unusual combination of technical and scientific areas; it is a new field of endeavor.

Both activities also have these elements in common: they are constantly changing • they are long-range in nature • they are essential to the welfare of the United States.

The close interrelationship of these two major projects, the widely diversified specialties involved in them, and the dominating influence of man-machine relationships make SDC's work unique. Operations Research Specialists, Engineers, Computer Programmers, Behavioral Scientists—all find their assignments reflect the unique qualities of this new field.

The expanding scope of SDC's work has created a number of positions in these fields. Inquiries are invited. Address: R. W. Frost, 2418 Colorado Ave., Santa Monica, California, or phone collect at EXbrook 3-9411 in Santa Monica.

SDC

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DEVELOPMENT
CORPORATION
Santa Monica, California

11-53A

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ORO starting salaries are competitive with those of industry and other private research organizations. Promotions are based solely on merit. The "fringe" benefits offered are ahead of those given by many companies.

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BETHESDA 14, MARYLAND

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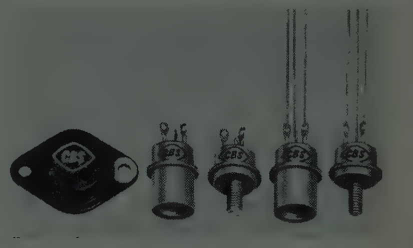
*(Continued from page 158A)*

choice of five packages—and thirty-six collector-to-base voltages and large signal current gains in 20- 30-, or 40-watt sizes.



Complete data on the over one hundred EIA, military and special types in this broad new line are available by writing to CBS-Hytron Advertising Service, Parker St., Newburyport, Massachusetts, and asking for Bulletin E-288.

## X-Band Rotary Waveguide Shutter

A compact rotary waveguide shutter has been developed, by **Microwave Associates, Inc.**, Burlington, Mass., for use in RG-52/U X-band applications. The new switch, designated MA-710, operates from 20 to 29 volt dc supply and exhibits greater than 30 db attenuation over the 8.5 to 9.6 kmc band while in the normally closed position. In the closed position the shutter sharply attenuates radar leakage power caused by nearby radars, thus preventing degradation or burnout of sensitive mixer or video diodes used in radar receiver circuits when the radar is not in use.

In pulsed radars a combination of the MA-710 mounted in the receive arm behind an appropriate X-band duplexer insures crystal protection from excessive leakage power under all normal service conditions whether the radar is operative or not.

In the open position the MA-710 insertion loss is less than 0.2 db over its specified bandwidth. Miniature ball bearings used to support the rotary vane element enhances the reliability of the shutter, reduces its power consumption, and provides rapid rotation from the open to

*(Continued on page 162A)*

# ASTRONAUTICS

**We are expanding the senior staff of our recently-formed Astronautics Laboratory.**

**Individuals must be capable of carrying full responsibility for advanced work in their fields.**

*These positions are open:*

- **Physicist or M. E.,** with both theoretical and practical strengths, to establish system requirements for infrared homing missiles.
- **Senior engineer** experienced in missile and rocket performance to establish requirements for launching equipment and procedure.
- **Physical chemist** to conduct theoretical analyses on chemistry of color photography, semi-conductors, and solid-state phenomena.
- **Physicist** to conduct theoretical analyses on nuclear phenomena, high-altitude measurements, and relativistic mechanics.
- **Optics theoretician,** with appreciation of hardware problems, to design and develop photoelectric devices, photo-conductive cells, and related optical devices and systems.
- **Senior mechanical engineer** to design and develop gyros, accelerometers, integrators, and related hardware for application in space guidance systems.

**Leading company, with an ideal location. Send confidential inquiries to: Mr. Charles Weinpel, Engineering Division**

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**NAVIGATION • TELEMETRY**
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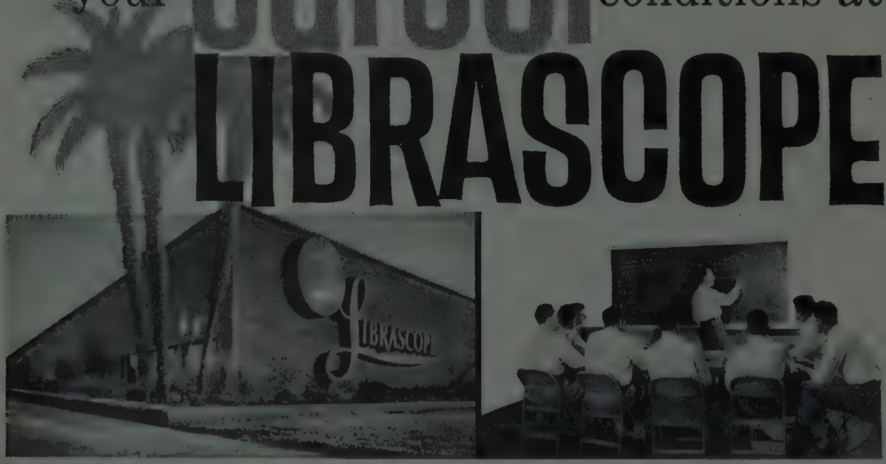

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**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.**

*(Continued from page 160A)*

closed position. Rotation time from the closed to open position is under 20 milliseconds and 40 milliseconds from the open to closed position. Except for the ball bearing support, the rotary vane does not contact the inner walls of the waveguide. A minimum travel of only 90° from the closed to open position further reduces physical wear of the vane so that electrical characteristics of the shutter should remain constant even after prolonged use.

Its compact construction (0.485 inch long) and total weight of less than 3 ounces favors its use in airborne or other mobile equipments. A dual version, MA-750, has been developed for use behind TR tubes in short slot hybrid duplexers. Both shutters are designed to operate under military conditions of shock, vibration, humidity, and temperature cycling over the −55° C to +125° C temperature range.

For detailed information contact the manufacturer.

## Direct Reading Attenuators

Now available from **Polytechnic Research & Development Co., Inc.,** 202 Tillary St., Brooklyn 1, N. Y., is a new series of 12 direct reading level set attenuators with frequency ranges from 2.6–3.95 kmc., 3.95–5.85 kmc, 5.85–8.2 kmc, 7.05–10 kmc, 8.2–12.4 kmc, 12.4–18 kmc, a maximum vswr multi-turn drives. Units in each frequency range are available with either 20 or 40 db maximum attenuation.

Convenient for both field and laboratory use, these additions to the Pacemaker line are suited to power level adjustments and as padding devices. Each attenuator comprises a section of waveguide containing a resistive vane parallel to the narrow face. The attenuation is increased by moving the metallized plate from the sidewall towards the waveguide center. A scale calibrated near the center frequency of the waveguide range provides direct reading of attenuation.

Featuring minimum leakage; a ruggedized, shock and moisture resistant lossy vane; bilateral matching elements for low vswr, each unit has an average power dissipation of 1 watt. Insertion length ranges

*(Continued on page 164A)*

*An invitation*
*to*
*senior scientists*
*and*
*engineers*

A $14,000,000 R & D Center, housing 9 new laboratories, was revealed as core of Republic's $35,000,000 Research and Development Program at recent announcement by Mundy I. Peale, President, and Alexander Kartveli, Vice-President for Research and Development.

# ....To join Republic Aviation's new $35 million Research and Development Program for spacecraft, missiles and advanced aircraft

In announcing Republic's $35 million research and development program, designed to arrive at major breakthroughs in the aviation industry's transition to astronautics, Mundy I. Peale, President, set the following objectives:

> "...ACCELERATION OF PROJECTS ALREADY UNDER WAY AT REPUBLIC ON LUNAR PROGRAM FOR MANNED SPACE VEHICLES, AND MISSILES TO DESTROY ORBITING WEAPONS, AND INITIATION OF INVESTIGATIONS LEADING TO NEW CONCEPTS FOR INTERPLANETARY TRAVEL."
>
> "...RADICAL NEW FAMILIES OF LONG-RANGE AIR-TO-AIR MISSILES AND AIR-TO-SURFACE BALLISTIC MISSILES FOR STRATEGIC AND TACTICAL AIRCRAFT."
>
> "...VERTICAL TAKE-OFF FIGHTER-BOMBERS, HIGH-MACH FIGHTER-BOMBERS, AND SUPERSONIC TRANSPORTS."

Alexander Kartveli, Vice-President for Research and Development, emphasized that Republic's program "will not duplicate in any way investigatory work currently in progress elsewhere, but will stress novel concepts and new approaches to basic problems of missiles and space technology."

The program includes construction of a $14 million R & D center to house 9 new laboratories, and anticipates doubling the present research staff.

Senior men interested in the new possibilities created by a simultaneous exploration of all aspects of Flight Technology are invited to study the functions of the new laboratories for more detailed information:

**SPACE ENVIRONMENTAL DEVELOPMENT LABORATORY**
To simulate space flight conditions and test missile, satellite and spacecraft systems and components; investigate human engineering problems.

**RE-ENTRY SIMULATION & AERODYNAMIC LABORATORY**
To study hypersonic shock dynamics, real gas effects, heat transfer phenomena and magnetohydrodynamics.

**MATERIALS DEVELOPMENT LABORATORY**
Study effects of high velocity, temperature, and space environment on materials for spacecraft, missiles and advanced weapons.

**GUIDANCE & CONTROL SYSTEM DEVELOPMENT LABORATORY**
To develop and test guidance and control systems for spacecraft, missiles and aircraft.

**ELECTRONICS DEVELOPMENT LABORATORY**
Study and explore all problems connected with highly specialized, complex electronic systems required for advanced forms of spacecraft, missiles and aircraft.

**ADVANCED FLUID SYSTEMS DEVELOPMENT LABORATORY**
To develop and test fluid power systems for spacecraft and missiles capable of operation under extremely high temperature, high pressure conditions.

**MANUFACTURING RESEARCH & DEVELOPMENT LABORATORIES**
To develop advanced manufacturing processes and techniques for materials used in missiles and spacecraft. Laboratories for each of the following areas: *Non-Metallics, Metallics, Welding.*

Qualified men are invited to write directly to:
A. Kartveli, Vice President, Research and Development

**REPUBLIC AVIATION**
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If you know instrumentation and equipment limitations, and are experienced in the design of setups, there is a career for you measuring strains, static and dynamic loads, temperatures and deflections.

Write to: Mr. B. K. Stevenson, Engineering Personnel, North American Aviation, Inc., Los Angeles 45, California.

THE LOS ANGELES DIVISION OF
**NORTH AMERICAN AVIATION, INC.**

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 162A)*

from $2\frac{11}{16}$ inches through 12 inches; waveguide dimensions range from 0.622×0.311 inch for the 12.4 to 18 kmc frequency range units to $3\times1\frac{1}{2}$ inches for the 2.6–3.95 kmc frequency range units.

For details, write to the firm.

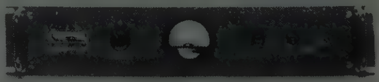
## NEREM
## November 19–20
## Boston, Mass.

NEREM Committee planning the Northeast Electronics Research and Engineering Meeting which will be held November 19–20 in the Mechanics' Building, Boston. The meeting, sponsored jointly by the Boston Connecticut, and Western Massachusetts section of the Institute of Radio Engineers, will feature a program of technical papers based on the theme, "Today's Electronic Developments—Tools for Tomorrow." Also featured will be 200 exhibits of electronic components and instruments.

Shown are: Seated (l. to r.) S. K. Gibson, exhibits; H. H. Dawes, general chairman; A. Winston, arrangements; M. C. Walker, registration. Standing (l. ro r.) J. J. Faran, program: R. A. Luoma; E. L. Pack; C. J. Lahanas; P. G. Yewell; J. C. Simons; R. R. Leonard, publicity; R. B. Hackenberger, treasurer.

## Deviation Meter

**Nems-Clarke Co., div. Vitro Corp. of America,** 919 Jesup-Blair Drive, Silver Spring, Md., announces the Type DM-100 Deviation Meter for use with many models of their receivers in telemetry applications. A similar deviation meter is built into the Nems-Clarke Type 1400 series receivers. This device is now available for use with other receivers in the line.



The DM-100, and its associated circuitry and power supply are mounted on a $3\frac{1}{2}\times19$ inch panel for rack mounting. In operation

*(Continued from page 166A)*

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ELECTRONIC TUBE PLANT
OF SPERRY
ELECTRONIC TUBE
DIVISION

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Electronic Tube Specialist

If you have a bachelor's degree in electrical engineering or physics with a minimum of 10 years' applicable experience we can make you a particularly interesting offer. Experience in vacuum tube manufacture helpful but not essential. Scope of responsibility includes ruggedized subminiature receiving tubes, ruggedized miniature tubes, planar triodes, thyratrons, special purpose microwave tubes.

You will supervise a special applications group responsible for liaison with major tube manufacturers, preparation of performance specifications, design and fabrication of special test equipment, surveillance of quality level and coordinating technical aspects in Bendix production.

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Mr. J. L. BRESLIN, Professional Personnel
BENDIX AVIATION CORP.
Box 303-BM, Kansas City Mo.

I am interested in receiving consideration for the position of Project Supervisor.

Name ....................................................

Street .................................... Phone ..........

City .................................... State ..............

20—NEWS-POST Baltimore, Fri., Aug. 1, 1958

Westinghouse Awarded $22 Million Navy Contract

The company's Friendship Airport plant will produce shipboard radio transmitters and radar equipment which it designed.

The radar particularly is considered a revolutionary breakthrough in electronics, permitting results identical to that achieved by conventional radar with 30 times the power.

R. E. KIRBY, manager of the electronic division, said there are actually three contracts involved.

One worth more than $8 million is for production of the advanced air-search radar. It is to be used on carriers, cruisers and other ships.

The second contract is for $1 million worth of conventional design radar.

The largest contract, more than $12 million, is for production of medium and high frequency communications transmitters. These would be used on surface ships and submarines.

"The new radar equipment," Kirby said, "employs a revolutionary electronic circuit technique considered a technological breakthrough in the evolution of shipboard air-search radar." It was designed and tested here.

The transmitter is the product of Westinghouse research begun in 1951.

This Navy contract is the result of another major technological breakthrough by our outstanding team of engineers at Westinghouse-Baltimore. An exciting opportunity exists for qualified engineers to join this team. You will be a part of our wide range new development program which will result in a continuing pattern of major breakthroughs in the future.

PARTIAL LIST OF CURRENT OPENINGS:

Digital-Analogue Computer Design
Transistor Circuitry
UHF Communications
Servo Control Loops
Electronics Circuitry
Intermediate Frequency Amplifiers
Microwave Components
Network Synthesis

TO APPLY: Send a resume of your education and experience to Dr. J. A. Medwin, Dept. 825, Westinghouse Electric Corporation, P. O. Box 746, Baltimore 3, Maryland.

Reprinted from the BALTIMORE NEWS POST

Westinghouse-BALTIMORE

YOU CAN BE SURE...IF IT'S Westinghouse

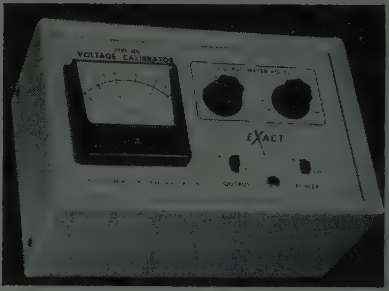
## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 164A)

the DM-100 Deviation Meter is bridged across the video output of the receiver. This unit permits a direct reading of the deviation in kilocycles of the subcarrier oscillators used in a telemetry system. A three-position switch is incorporated in the unit permitting full scale readings of 25, 50, and 75 kc.

### Voltage Calibrator



**Exact Electronics, Inc.,** P. O. Box 552, Portland 7, Ore., recently announced a new Type 100 voltage calibrator primarily designed for the accurate calibration of oscilloscopes, ac or dc voltmeters, and measurement types of test equipment. The main feature of the Type 100 is the $\frac{3}{4}$ per cent accuracy of the directly metered dc or symmetrical 1 kc square-wave output. This direct metering of the output voltage gives accurate results under conditions of extreme external loading. Output range is continuously variable from 0.02 volt to 100 volts.

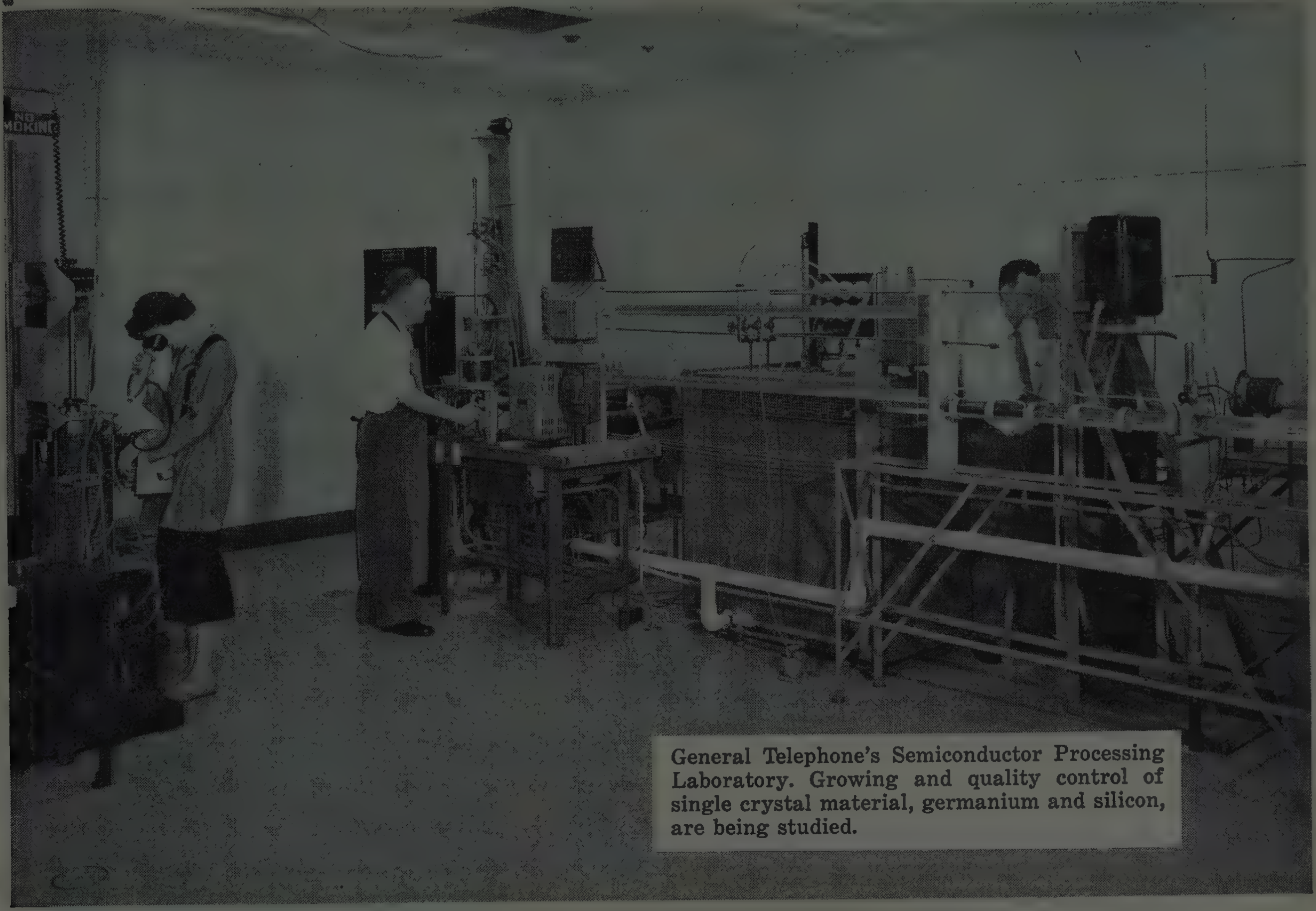
### The Frame Grid Tube

The frame grid tube, a recent significant advance in tube design, is now being mass produced in the United States by **Amperex Electronic Corp., Special Purpose Tube Div.,** 230 Duffy Ave., Hicksville, L. I., N. Y.

The Amperex frame grid construction makes it possible to use extremely fine wire

(Continued on page 168A)

*The GENERAL Idea on Engineering Careers*



General Telephone's Semiconductor Processing Laboratory. Growing and quality control of single crystal material, germanium and silicon, are being studied.

# Tomorrow's telephone switching "memory"

New all-electronic methods of telephone switching will require extensive memory systems—for both long- and short-term storage.

This work is challenging the best creative talents of many physicists and electronics engineers at General Telephone Laboratories.

In our Research and Development program we are exploring such techniques of memory as magnetic cores, drums, tape, delay line, electrostatic and photographic. Specific projects include research in solid-state materials, ferrite cores, germanium and silicon semiconductors.

This is, of course, only one phase of our work at General Telephone Laboratories. But it illustrates the point that the physicist or engineer looking for an interesting challenge to mature abilities is likely to find it here.

As the research and development arm of General Telephone System and Automatic Electric, our manufacturing affiliate, General Telephone Laboratories offers a rare combination of advantages—an engineer's company—serving stable but fast-growing industries—pleasant surroundings near Chicago's many universities—broad opportunities for personal growth.

• • • • • • • • • • • • • • • • • • • • • • •

*If you have* your Doctorate in Physics or Electrical Engineering, we have a particularly attractive opening for you. We'll gladly give you more specific information if you will write, in confidence, to Mr. Robert Wopat, President, General Telephone Laboratories, Northlake, Illinois.

**GENERAL TELEPHONE LABORATORIES**

GENERAL SYSTEM

*I want a "Whatcha-ma-call it?"*

*It's a "thinga-ma-jig that ......"*

How often have you struggled to remember the name of a component or electronic item. . . . Just could not think quickly what it is called?

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(2) Its listings are fundamental—the way an engineer thinks

(3) "Terminology" is cross indexed in the pink pages—condensed, simple, not mixed in with firm names.

(4) Ads face listings thus helping to identify products by actual pictures.

(5) Product code numbers reduce complex and duplicate listings, saving you "searching" time and effort.

*Study it . . . save it . . . work it.*

THE INSTITUTE OF RADIO ENGINEERS

1 East 79th Street, New York 21, N.Y.

## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 166A)*

for the grid and achieve the closest approximation now practical to the physicist's "ideal" grid. This ideal is an infinitely thin conducting plane which offers no resistance to the passage of electrons except that due to its electrostatic potential. The frame grid construction also results in vastly increased gain-bandwidth product, transconductance and insensitivity to microphonics, all of which make feasible the design and manufacture of more compact and reliable tubes.

What the frame grid is and does, may best be understood by comparing it with a conventional grid. In conventional grid construction, molybdenum grid wire is wound helically around two metal supporting rods in which grooves are cut to hold the grid wire in place; the grooves being closed under pressure after the winding is completed. In this type of construction the grid wire performs both a mechanical and an electronic function. It physically supports the metal rods and, together with two mica spacers, holds them apart at the correct distance. However, this "correct" distance is difficult to maintain because the mica spacers cannot be manufactured to sufficiently close tolerances and the wires, being under tension during the manufacturing process, deform somewhat when released.

In the frame grid construc tion however, the grid wires have only an electronic function, the mechanical being fulfilled by a sturdy self-supporting frame consisting of two molybdenum centerless ground rods connected by four spot-welded molybdenum strips. The rods, which can be manufactured to within a tolerance of 0.005 millimeter (0.00019 inch), determine the clearance between the turns of wire on opposite sides of the frame. This clearance and its accuracy largely determines the grid-cathode spacing, which in turn determines gain-bandwidth product and transconductance.

Very thin tungsten wire, 0.0075 millimeter (0.00029 inch) in diameter, is tightly wound around the frame. The winding tension is about 60 per cent of the tensile strength of the wire. This high tension makes it possible to position the grid wires more accurately and have them maintain their position throughout the life of the tube.

There are several reasons why the frame grid improves performance and reliability. In a vacuum tube, the grid-to-cathode spacing is of prime importance in determining the gain-bandwidth product; the closer the spacing, the higher the product. With the frame grid construction, grid-to-cathode spacing can be reduced to 0.05 millimeter (0.0019 inch), resulting in an increase of the gain-bandwidth product as much as double that obtainable with standard grid construction.

Another factor increasing the efficiency

*(Continued on page 170A)*

In
ELECTRONICS

# Temco

AIRCRAFT
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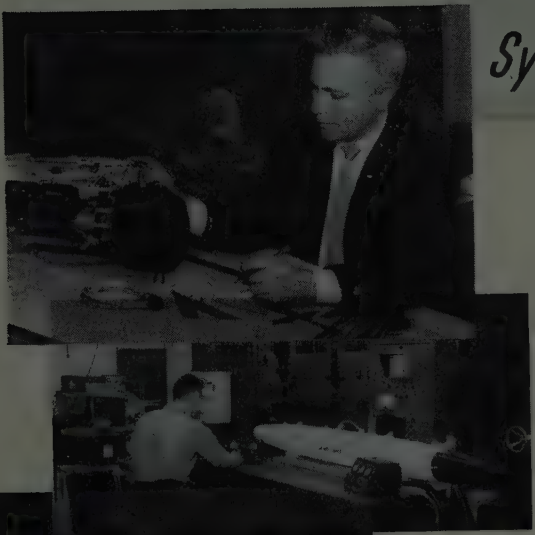
means a

## *System of Weapons Management*



Temco's capabilities in electronic research and development .. in systems management .. are making Temco a leader in the electronics field. Take Temco's work in autopilot development, for example. While converting several Army Signal Corps L-17s to radio-controlled reconnaissance drones, Temco found no suitable "commercial" autopilot. So Temco engineers developed their own .. an inexpensive, simplified unit that met all special requirements .. provided wide-range reliability and control.

Then Temco engineering came up with a low-drift d-c servo system and a low-power d-c "pecking" amplifier .. took the basic autopilot they had developed .. miniaturized and repackaged it for use in Temco's rocket-powered transonic Teal target drone. The result: "Teal" became the first "missile" of its type to be successfully launched from a swept-wing aircraft and to operate effectively at altitudes up to 50,000 feet.

Today this know-how is directing development of "Corvus" .. the Navy's highly classified "stand-off" air-to-ground missile .. with Temco as weapon system manager. It is being used in the development and production of special flush-mounted antenna systems .. microwave devices .. advanced guidance systems .. airborne TV systems and many classified projects.

**Temco's complete systems management capabilities are ready to meet your challenge.**

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SPECIFICATION MIL C 10/950 A

| C | $\frac{\Delta C}{C \Delta \theta}$ | Stability |
|---|---|---|
| $12 \leqslant C \leqslant 1000$ | $0 \leqslant \frac{\Delta C}{C \Delta \theta} < 70.10^{-6}$ | $\pm (5.10^{-4} \pm .1\ pf)$ |

- Mica Capacitors "STABILIDISC"

| C | $\frac{\Delta C}{C \Delta \theta}$ | Stability |
|---|---|---|
| $12 \leqslant C \leqslant 1000$ | $15.10^{-6} \leqslant \frac{\Delta C}{C \Delta \theta} \leqslant 45.10^{-6}$ | (high stability)<br>$\pm (3.10^{-4} \pm .1\ pf)$ |

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G. C. Dewey&Co.,Inc. acts as prime contractors to Government and Industry on problems involving the analysis and engineering of future weapons systems and the application of the most recent advances in science and technology. The corporation's staff of scientists and engineers apply the techniques of

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*(Continued from page 168A)*

of frame grid tubes is the excellent heat dissipation properties of the frame grid structure. The relatively large mass of the frame structure dissipates heat faster than a conventional grid, resulting in a cooler operating tube.

The frame grid construction also achieves greater reliability because there is less spread in characteristics before and during use. Variations due to the manufacturing process are at a minimum because the frame grid structure is such that automatic tooling can be used to produce the high degree of conformity necessary for consistent electrical characteristics. The rigidity of the frame grid structure also makes for a tube that is insensitive to microphonics.

Amperex frame grid tubes are especially valuable for use in computers, unsupervised equipment, instrumentation and communications applications, and wherever tubes with high reliability and longer life are needed.

For further information write to the firm.

## Electronic Stopwatch

A new Electronic Stopwatch, for measuring time intervals between opening and closing of contacts on virtually any instrument or control, has been developed by the **Dynapar Corp.**, 5150 Church St., Skokie, Ill.

Called the Dynatimer Electronic Stopwatch, the instrument is available with either glow counter tube or "Nixie" neon tube readout, for direct numerical reading in milliseconds. Accuracy: ±one millisecond. Range: contact time intervals from 2 milliseconds to 10 seconds. Several time intervals may be automatically totaled.

Designed for simplified operation in any application where precise contact timing is critical, no adjustments necessary. Another model offers special advantages when measuring operating time of relays, from the instant the power switch is actuated to the precise instant when the

*(Continued on page 172A)*

*now available:*

## ULTRAMICROWAVE* EQUIPMENT TO 140,000 MC –PRECISION BUILT BY DE MORNAY-BONARDI

Instruments are now in production at D-B which extend microwave research to 140 KMC—with continuous coverage from 2 KMC. The higher frequency units give you vastly more leeway in designing and experimenting. They give you resolutions better by 10 to 1, and the option of using working models only 1/10 actual size.

Extremely high precision is characteristic of these ultramicrowave instruments. D-B has employed unique design and production techniques to achieve a mechanical accuracy consistent with the wavelengths involved. These instruments are not scale-ups of our longer wavelength equipment—they are newly designed to meet the small tolerances required. Calibrations are available at several points.

De Mornay-Bonardi is ready to help you in setting up test equipment, or planning special systems. Draw on our 15 years' experience in microwaves.

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BREAKDOWN FAILURES

NEW
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MOLDED
DEPOSITED CARBON RESISTORS

The use of a thermo-plastic insulation material has resulted in an economically priced molded carbon resistor of markedly improved endurance and long term stability.

Type N resistors subjected to several one-hour cycles of immersion in boiling water — while DC polarized — have revealed only negligible changes in resistance. Continuous operations at 150°C caused no damage to the component.

The new Type N resistor, a deposited carbon film fired onto a porcelain rod, is first tropicalized with multiple coatings of panclimatic lacquers to give it long term moisture resistance, and is then molded in a thermo-plastic material.

This molded insulation has an effective resistance in the order of $10^{13}$ ohms. Its inherent thermal conductivity is approximately ten times that of air, resulting in substantially improved load life under conditions involving excessive or high wattage dissipation. Similarly, Type N resistors may be soldered as close to the insulation as desired without fear of melting or deforming the cover.

One added advantage of the Type N is that the original markings on the resistor body remain visible and legible through the transparent molded material.

Welwyn Type N carbon resistors meet the requirements specified by MIL-R-10509B, and are available in all values, ranging from 10 ohms through 1 megohm. For complete data and specifications write to Welwyn International, Inc., 3355 Edgecliff Terrace, Cleveland 11, Ohio.

SAMPLES AVAILABLE ON REQUEST.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 170A)*

contact opens or closes (also to ±1000th second accuracy). Extremely compact, lightweight (12 lbs.), and completely self-contained.

## Welding Power Supply Offers 500-Watt-Second Output

Controlled output from 2 to 500 watt-seconds is now available in a new resistance welding power supply offered by **Weldmatic Division of Unitek Corp.,** 380 North Halstead Ave., Pasadena, Calif.

Supplying twice the energy previously available in electrolytic capacitor-discharge supplies, the new Model 1024 is engineered for heavy-duty applications. Uniform and reliable welds can now be made on difficult metals and large assemblies without water cooling. Deformation and discoloration are minimized, and there is no electrode burn-off or operator shock hazard.

Operating from any 105–125 volt, 60 cps power outlet, the Model 1024 works with the controls and welding transformer of a separate welding head or handpiece to form a heavy-duty welding team. Voltage regulation is automatic, assuring uniform welds. All circuitry is completely enclosed for safety, yet accessible for servicing. The 6400-μf capacitor bank is mounted in a convenient pull-out drawer. A forced-air cooling feature of the unit enables rapid cycling on production runs.

For further information write to the firm.

## Dual Preset Counter

A dual preset counter-controller has been introduced by **Computer Measurements Corp.,** 5528 Vineland Ave., North Hollywood, Calif., manufacturer of high speed electronic counting equipment. The

*(Continued on page 174A)*

# Professional Group on Medical Electronics

For centuries mankind has searched for a fuller knowledge of the workings of the human body and for improved means of diagnosing and curing bodily ailments. This noble task has been greatly aided in recent years by the application of electronics to medicine and related fields.

Electronics has provided the physician with the means for making better, more exact, more comprehensive measurements of countless parameters important to his work. As a result he now knows a great deal more about the brain, heart, blood, respiratory system, tissue, muscle, and nervous system.

Having thus increased his knowledge, the doctor has turned to electronics also for assistance in the treatment of disease. Cancer therapy, the location of tumors, diathermy, and the treatment of heart diseases are but a few examples of the uses to which electronic equipment and techniques are being put.

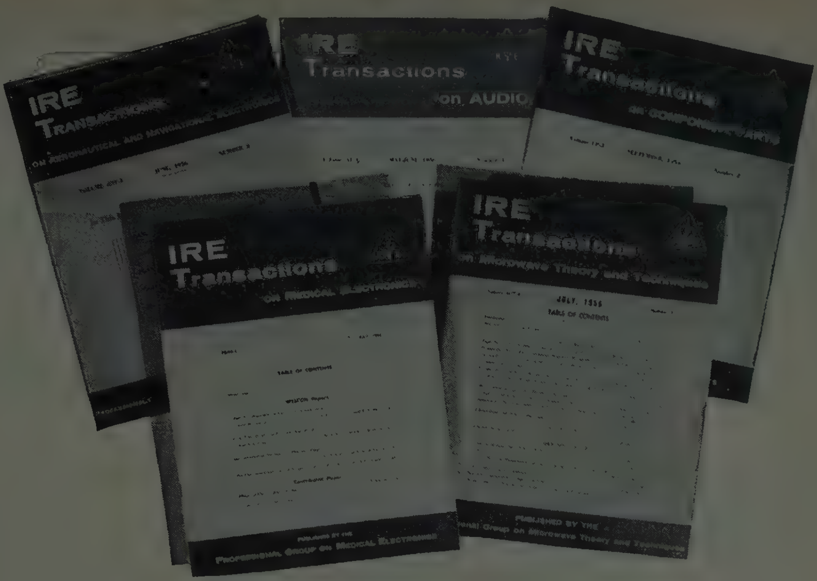
To provide the medical field with the necessary electronic equipment, almost every branch of radio engineering has been called into play: from ultrasonics to X rays, from dc amplifiers to microwave apparatus, aids for the blind and aids for the deaf, electronic recording and mapping devices. Even television has supplied an important and useful tool, the television microscope.

However, the rapid development of medical electronic equipment has been hampered by a serious obstacle. For here was a situation which called for the combined knowledge of two highly skilled and hitherto unrelated fields. Either the doctor would have to become an engineer or vice-versa, unless some common meeting ground could be provided to enable an exchange of vitally needed information.

It was to meet this urgent need that the IRE Professional Group on Medical Electronics was formed. Already 1800 strong, the Group is actively engaged in publishing valuable technical papers and sponsoring national meetings, thereby providing the only organized activity of its kind in this vital field.

W. R. G. Baker

**Chairman, Professional Groups Committee**



# At least one of your interests is now served by one of IRE's 28 Professional Groups

**Each group publishes its own specialized papers in its *Transactions*, some annually, and some bi-monthly. The larger groups have organized local Chapters, and they also sponsor technical sessions at IRE Conventions.**

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| Antennas and Propagation (G 3) | Fee $4 |
| Audio (G 1) | Fee $2 |
| Automatic Control (G 23) | Fee $2 |
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IRE Professional Groups are only open to those who are already members of the IRE. Copies of Professional Group Transactions are available to non-members at three times the cost-price to group members.

**The Institute of Radio Engineers**
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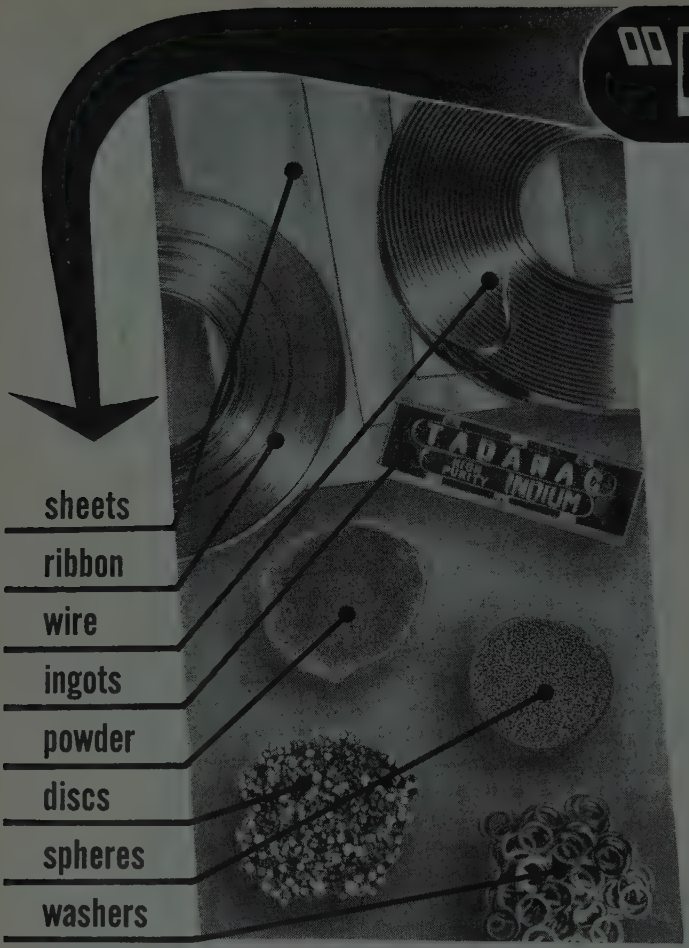

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Students, former students and graduates of both the CREI Home Study Course and the Residence School are invited to join the CREI Alumni Association. Write us, we'll put you in touch with the nearest Local Chapter of the Association. If there isn't one near you, we'll give you names of other Alumni in your area and tell you how you can start a chapter. Write to the Executive Secretary, CREI Alumni Association for full particulars. If you are not receiving the Alumni quarterly report or the Monthly CREI Times send us your name and address. We'll be glad to add your name (Mention the "Proceedings of IRE").

## NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 172A)*

new instrument is designed to solve control problems such as motor over-speed, shearing to length, high speed coil winding, weighing, sorting, packaging, metal forming, computer timing and programming, and variable pulse generation.

The new dual preset counter-controller is a direct-reading electronic counter which provides output information in the form of pulses and relay closures at any two preselected counts within the capacity of the unit. Capable of operating at rates up to 40,000 counts per second, the instrument

*(Continued on page 176A)*

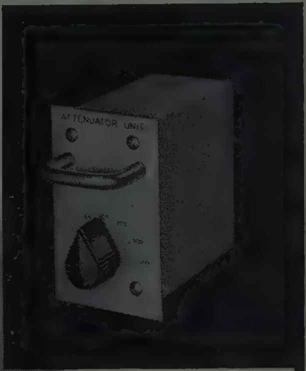
# New Electro Instruments A-12 DC amplifier totally transistorized

## equal to or better than the best vacuum tube instruments!

The new Model A-12 DC Amplifier is the preferred systems link for amplification, normalization and impedence transformation. Use of solid state elements assures maximum reliability; power dissipation is only seven watts. Mil-type components are mounted on coated plug-in printed circuit boards for protection against vibration and corrosion.

**versatility plus economy**

Electro Instruments produces a series of plug-in mode selectors and attenuators for the A-12: single ended, differential and operational, fixed and variable gain.



ATTENUATOR UNIT
MODEL A-12 DC AMPLIFIER

**Eight to a rack**
The A-12 is packaged for high density use; mounts eight across in 19″ relay rack panels.

## SPECIFICATION SUMMARY

| | Single Ended Input |
|---|---|
| **Gain:** | Fixed gain set to any value from 10 to 1000 inclusive by front panel plug-in units. Gain switching plug-in attenuator available with gains of 0, 10, 20, 50, 100, 200, 500 and 1,000. Adjustable upward 6db from setting with potentiometer. |
| **Input Impedance:** | 100 megohms shunted by 0.001 mfd (typical). |
| **Source Impedance:** | 5K or less (to meet noise specification). |
| **Drift:** | Less than 2 microvolts in 200 hours at constant ambient temperature. Less than 0.4 microvolt per degree centigrade. |
| **Ambient Temperature:** | 0° to 50°C. |
| **Noise (Referred to input):** | 0-3 cps 5 microvolts peak to peak<br>0-750 cps 4 microvolts rms.<br>0-50 kc 8 microvolts rms. |
| **Frequency Response:** | ±3db to 50 kc (typical); ±1.0% to 2 kc |
| **Output Capability:** | ±10 volts at ±100 ma DC or peak AC to 10 kc |

*Write today for complete specifications on single-ended, differential and operational models.*

EI

**Electro Instruments, Inc.**
3540 Aero Court
San Diego 11, California

NOW FEATURING NEW CIRCUITRY

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DYNAMIC CAPACITOR ELECTROMETER

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*with $10^{12}$ ohms resistor*

- 10—100—1000 mv scales
- $10^{-5}$ to $10^{-14}$ amps full scale
- Less than 1 mv drift per day
- Accuracy ± 2%
- Input resistance $10^{15}$ ohms
- Short response time

**MODEL 202**
Price $1,075
FOB Carlstadt, N. J.

The Curtiss-Wright Dynamic Capacitor Electrometer is both a highly sensitive millivoltmeter and a micro-microammeter. It can be used to read low potentials originating in high impedance sources, insulation resistance, grid currents, static charges, etc., and as a null detector. In physics and chemistry, it provides measurement of pH ion currents in mass spectrometry. Its low drift permits reliable detection of radioactivity for health physics and reactor control. For complete information, write: Electronic Equipment Sales Dept.

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NATIONAL ELECTRONICS CONFERENCE, INC., 84 E. Randolph Street, Chicago 1, Illinois

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

*(Continued from page 174A)*

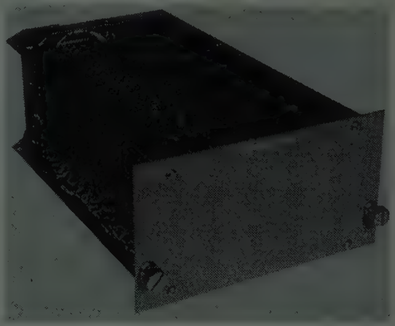
obtains input information from any standard transducer, photocells, tachometers, flow and pressure pickups, switch closures, and so forth.

Notable among the design features of the instrument is "unique digit circuitry" which extends the apparent range of the instrument. In some applications, a 3 digit instrument is capable of providing the same information which previously could be obtained from a 4 digit instrument. The new instruments also have four modes of operation, one more than heretofore available. Prices for the new instrument range from $165 to $915 according to the number of digits required.

For complete technical information, please write to the firm.

## Quarter Square Multiplier

Designed to fit neatly into present analog computer rack openings, the Model 7007, Quarter Square Multiplier by **Electronic Associates, Inc.,** Long Branch, N. J., adds new reliability, and frequency response to any analog computing facility.



This new computing element utilizes a variation of the quarter square multiplication technique and avoids the need for internal amplifiers. Thus, an improvement in frequency response is obtained over servo and time division techniques. For the first time, a multiplier is available whose dynamic characteristics approximate those of the computing amplifiers. As a result, repetitive operation at much higher rates becomes a routine operation.

Silicon diodes and ultra-stable resistors are used throughout to minimize drift and insure long maintenance free life. Components such as vacuum tubes and servo potentiometers with limited life are eliminated completely. Preventive maintenance schedules can be reduced appreciably.

Very low noise and infinite resolution result from elimination of servo potentiometers and time division oscillators. Multiplier 7007 noise has an essentially flat spectrum out to 10 kc and is slightly greater than the noise occurring in the standard computing amplifiers.

*(Continued on page 178A)*

# Do You Have Critical Filter Problems?

*Sangamo Electric Company has been designing and building specialty filters since 1927. These filters have been used in a wide variety of metering, telephone and military equipment produced by Sangamo, and by a limited group of electrical and electronic manufacturers. Sangamo's thirty years of filter design and manufacturing experience is now available to the industry.*

SANGAMO
MAY HAVE THE
ANSWER TO YOUR
PROBLEM

**Here's a Typical Example:** The filter illustrated was required for use in a circuit which was designed to amplify extremely small signals in the range of 25 KC to 26 KC.

### BASIC OPERATIONAL AND DESIGN SPECIFICATIONS:

Meet applicable requirements for military apparatus.

Operate in a plate circuit of an amplifier presenting an effective generator impedance of 47,000 ohms and to drive the grid circuit of the following amplifier stage.

Operate at signal level as low as 10 microvolts.

Must be well shielded against external fields.

Passband ripple not to exceed 1 db. from 25 KC to 26 KC.

Minimum rejection shall be 35 db. at 28 KC and 40 db. at 23 KC.

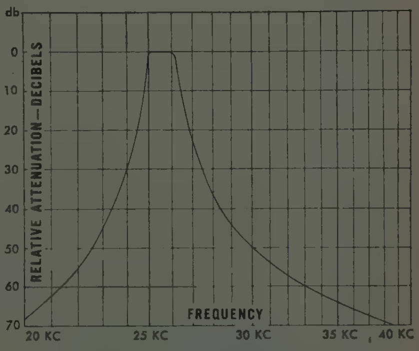
The phase shift, from one production filter to another, shall not vary more than 5° at any point in the 25 KC to 26 KC bandpass.

The phase shift and attenuation characteristics must be reproducible over a long period of years to insure properly functioning spare parts.

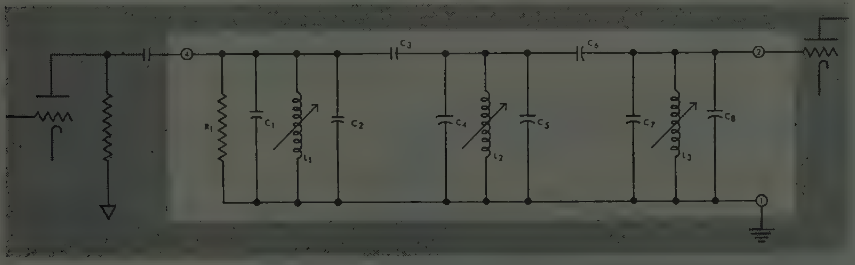
Temperature range 0° to 85°C.

### SANGAMO SOLUTION TO PROBLEM

The above requirements were met by using three parallel tuned circuits properly coupled by capacitors. Selection of the L-C ratios, coupling, and circuit Qs were made in order to fulfill the overall response requirements and at the same time present the proper load to the driving amplifier stage. Stability requirements were obtained by using Sangamo silvered mica capacitors. Negative temperature coefficient capacitors were inserted in parallel with the tuned circuits to correct for the positive temperature coefficient of the inductors. A phase shift variation of 2.5° maximum from 25 KC to 26 KC has been consistently maintained during eight years of production on these units. The universal wound coils are enclosed in powdered iron cups with moveable slugs for precise adjustment of the response and the phase shift. These inductors manufactured by Sangamo have uniform distributed capacity and Q. The cup-enclosed inductance coils are in turn housed in a die-cast aluminum enclosure. This housing lends physical rigidity to the coupled structure and assists in minimizing magnetic interaction between the enclosed inductors. The entire filter assembly is enclosed in a hermetically sealed drawn steel case. The terminals are of the extremely rugged compression glass type.



Relative response curve of this Sangamo bandpass filter.



$C_1$, $C_4$, $C_7$—Temperature Compensators
$C_2$, $C_3$, $C_5$, $C_6$, $C_8$—Sangamo Silvered Mica Capacitors

Write us today for an engineering analysis of your specialized filter applications. Sangamo's engineers are ready to help you.

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look what $24.50 buys in test equipment!

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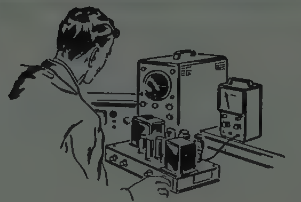
The famous model V-7A Vacuum-Tube-Voltmeter is a perfect example of the high-quality instruments available from Heath at ½ the price you would expect to pay! Complete, only $24.50



Get the most out of your test equipment budget by utilizing HEATHKIT instruments in your laboratory or on your production line. Get high quality equipment, without paying the usual premium price, by dealing directly with the manufacturer, and by letting engineers or technicians assemble Heathkits between rush periods. Comprehensive instructions insure minimum construction time. You'll get more equipment for the same investment, and be able to fill your needs by choosing from the more than 100 different electronic kits by Heath. These are the most popular "do-it-yourself" kits in the world, so why not investigate their possibilities in your particular area of activity! Write for the free Heathkit catalog now!

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*(Continued from page 176A)*

## Magnetic Amplifier Relays

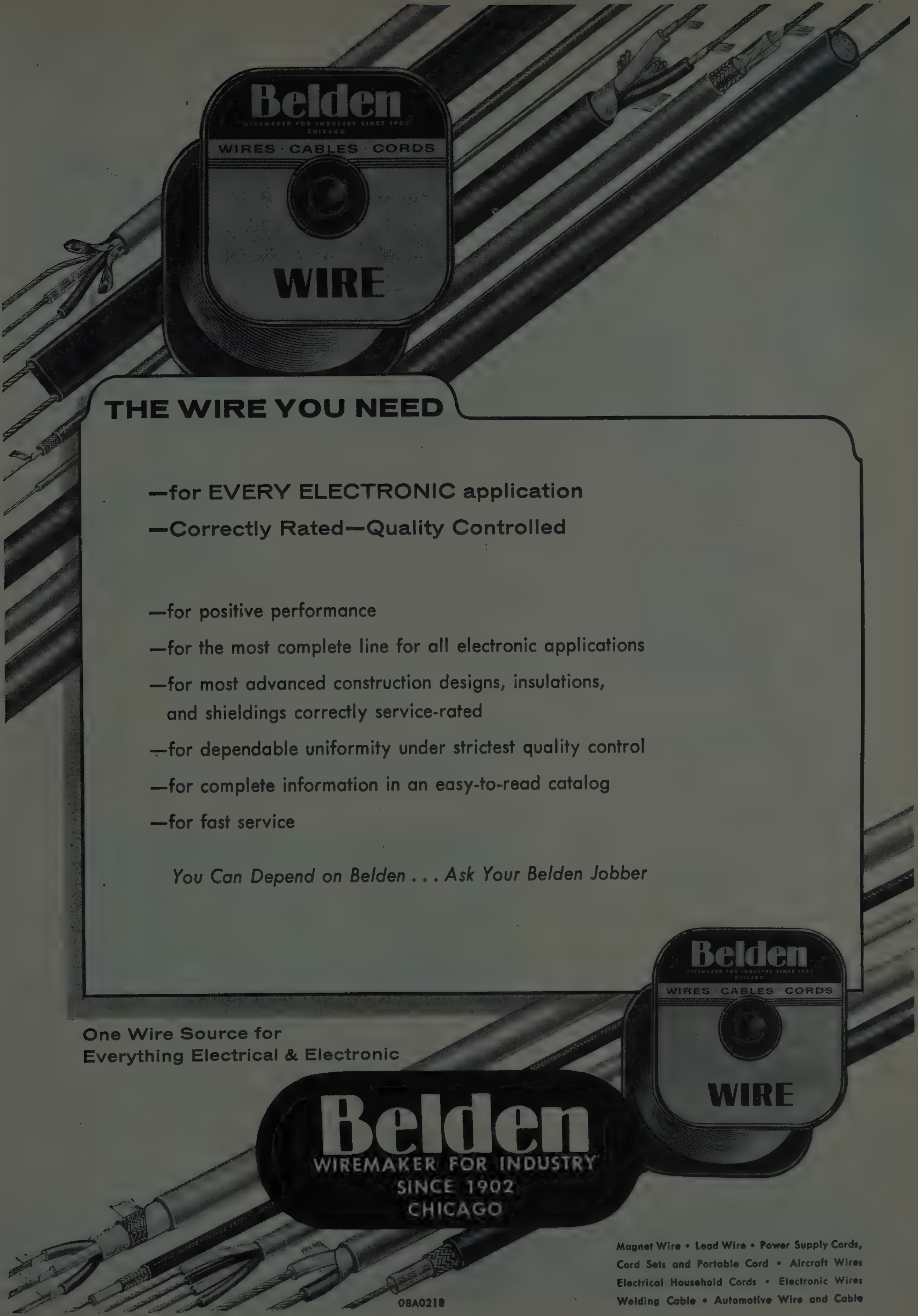
A new series of magnetic amplifier relays have been developed by **Ad-Yu Electronics Lab., Inc.**, 249 Terhune Ave., Passaic, N. J. For application in guided missiles, rocket research, as well as for industry and military applications.

Type RL-101 is especially designed for high current capacity, suitable for industrial applications. The excitation is 25.2 ± 3 volts rms, 60 ± 5 cps, 4 watts. The sensitivity is 140 microwatts. The response time is 0.5 second, decreasing to 0.15 second for signal sources of internal resistance of 3500 ohms or more. The contacts are dpdt each rated at 15 amperes, 28 volts dc or 115 volts ac. The dimensions are $2\frac{1}{8}\times2\frac{1}{4}\times5$ inches.

Type RL-102 is designed for high sensitivity, suitable for industrial and shipboard applications. The excitation is 6.3 ± 0.7 volts rms, 60 ± 5 cps, 0.8 watt. The sensitivity is 40 microwatts. The response time is 0.4 second, decreasing to 0.12 second for signal sources of internal resistance of 3800 ohms or more. The contacts are dpdt each rated at 2 amperes, 28 volts dc or 115 volts ac. The dimensions are $1\frac{5}{8}\times1\frac{7}{8}\times3\frac{3}{4}$ inches. This relay can stand vibration up to 55 cps at 10g with no contact chatter.

Type RL-103 is miniature size suitable for airborne applications. The excitation is 26 ± 3 volts rms, 400 ± 40 cps, 1.3 watts. The sensitivity is 80 microwatts. The response time is 0.6 second, decreasing to 0.1 second for signal sources of internal resistance of 5000 ohms or more. The contacts are dpdt each rated at 2 amperes, 28 volts dc or 115 volts ac. The dimensions are $1\frac{17}{64}\times1\frac{17}{64}\times1\frac{15}{16}$. The weight is 7 ounces. This relay can stand vibration up to 500 cps at 10g with no contact chatter.

*(Continued from page 180A)*



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At sea, in the icy cold of the antarctic! S.S.WHITE Molded Resistors in values up to 50,000 megohms retain their characteristics.
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Our resistors are characterized by low noise level . . . precision . . . stability . . . have negative temperature and voltage coefficients. Compact . . . excellent stability and mechanical strength . . . values do not deteriorate due to age.

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10 East 40th Street
New York 16, New York

## NEWS New Products

**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.**

*(Continued from page 178A)*

## Electronic Specialty Releases Complete Products Brochure

**Electronic Specialty Co.,** of 5121 San Fernando Rd., Los Angeles 39, Calif., announces the publication and availability of a new 32-page brochure, No. RS 100, describing the complete facilities and latest products of the Radiating Systems and Components Division.

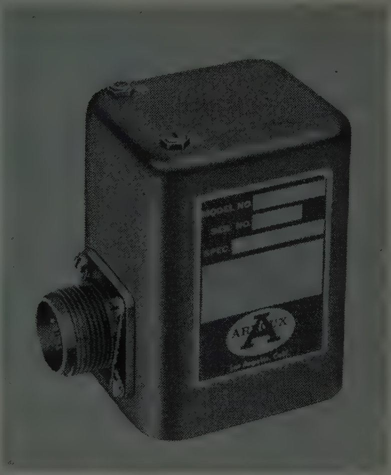
This is the most complete brochure of its type on matched radiating systems. It contains detailed component data on Antennas, Antenna Arrays, Coaxial Switches, Power Dividers, Filters, Diplexers and Multiplexers, Impedance Matching Devices, Coaxial Cable Assemblies and Complete Antenna Systems.

The facilities and capabilities of the Radiating Systems Division include the Antenna Research and Development Group, the Micro-Wave Component Group and the Mechanical Design Group. This brochure gives various examples of typical projects in systems and components capabilities.

For a copy of this engineering brochure No. RS 100, write on company letterhead.

## Transistorized Temperature Measurement Equipment

**Arnoux Corp.,** 11924 W. Washington Blvd., Los Angeles 66, Calif., has developed a new, transistorized, high-sensitivity version of their miniature temperature-measurement subsystems. Applications are missile and aircraft flight testing.



This latest series—TME-1SD and TME-2SD—are for use with fast-response, 100-ohm-resistance temperature transducers to produce a full 5-volt output for a span of only 75°F. TME-1SD is a single-

*(Continued on page 182A)*

**Make your Ferrites with**

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These reactive synthetic MAPICOS, some especially developed for ferrite manufacture, are over 99% pure $Fe_2O_3$. Choice of suitable characteristics is made easy—many variations in particle-size and shape are available. Careful control contributes to uniformity of packing and shrinkage. Our iron oxide production experience and our ferrite research can help you accomplish best results. Manufactured in modern plants by modern methods. Experienced Columbian technicians are ready to cooperate in any problem involving the use of iron oxides for ferrite manufacture. For full data and a working sample, write . . . today!

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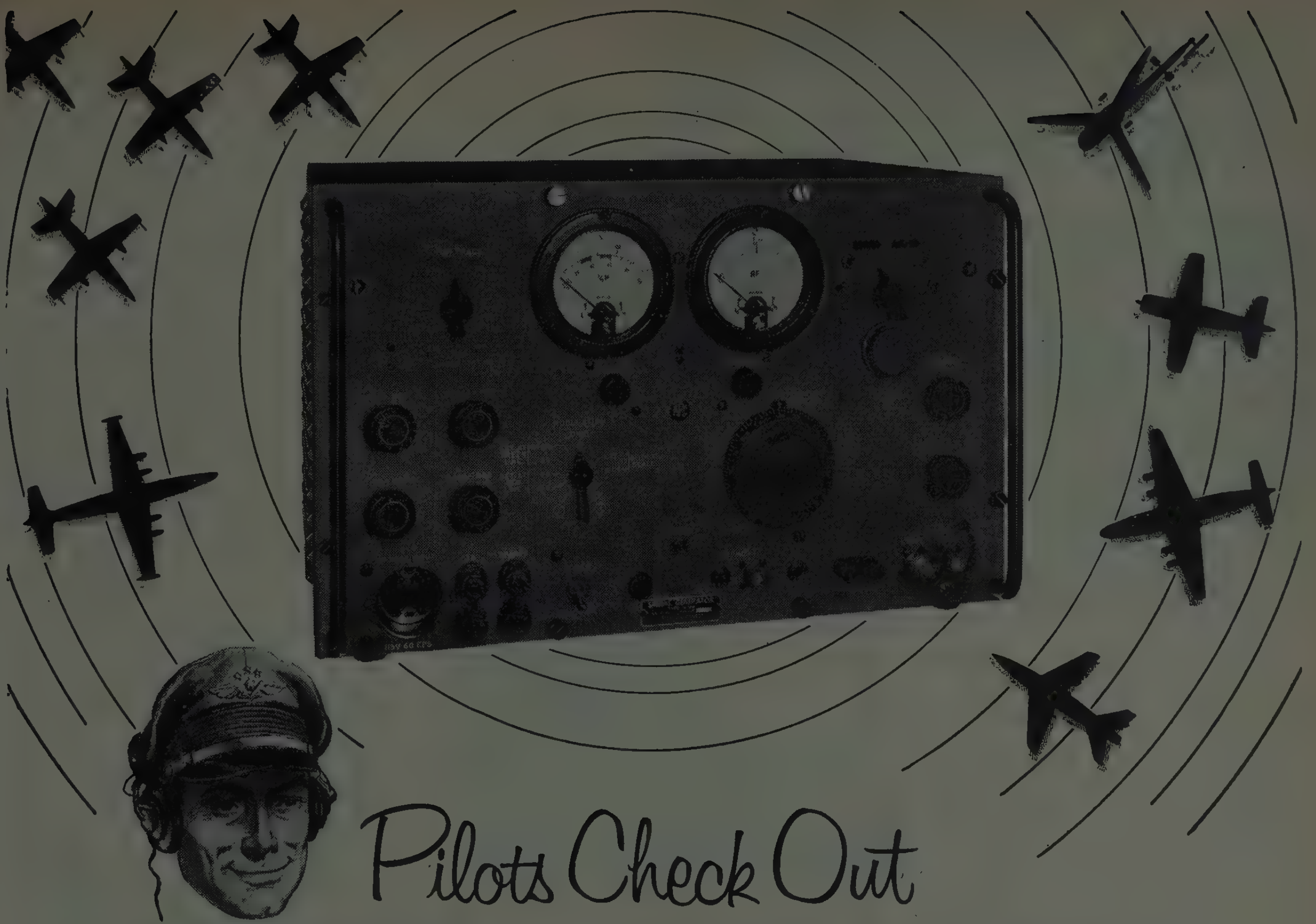

# Pilots Check Out

# NAVIGATION RECEIVER ACCURACY

## ARC Type H-14A Signal Generator Checks Omni/Localizer Equipment

ARC's H-14A Signal Generator provides a simple and dependable means of checking *omnirange* and *localizer receivers* in aircraft on the field, by sending out on the hangar antenna a continuous test identifying signal that blankets the field. Tuned to this signal, individual pilots or whole squadrons can quickly test their own equipment. Voice can be transmitted simultaneously with signal. The instrument will check 24 omni courses, omni course sensitivity, operation of TO-FROM meter and flag-alarms, left-center-right on 90/150 cps localizer, receiver frequency calibration, reciprocal course accuracy, and receiver output. The H-14A is also widely used for making quantitative measurements on the bench during receiver maintenance. Input power is 160 watts, 115 volts 60 cps.

The H-16A Standard Course Checker measures the accuracy of the indicated omni course in ARC's H-14A or other omni signal generator to better than ½ degree. It features a built-in method of checking its own precision.

ARC's Type H-12 Signal Generator (900-2100 mc) is equal to military TS-419 U, and provides a reliable source of CW or pulsed rf. Internal circuits provide control of width, rate and delay of internally-generated pulses. Complete specifications on request.

*Dependable Airborne Electronic Equipment Since 1928*

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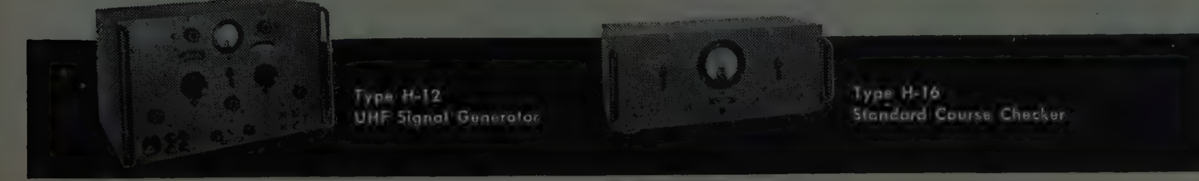
Interphone Amplifiers • Omnirange Signal Generators and Standard Course Checkers • 900-2100 Mc Signal Generators



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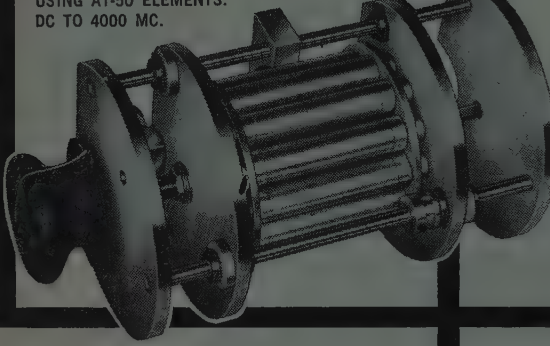

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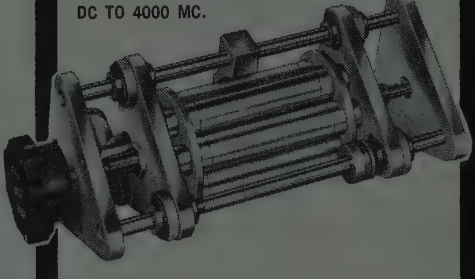
Empire's UHF attenuators are resistive coaxial networks for the frequency range from DC to 4000 MC.

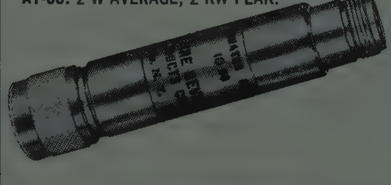
Accuracy is held to ±½ DB, VSWR is better than 1.2 to 1. Any attenuation values up to 60 DB (120 DB for Model AT-106), are available. Deposited carbon elements are used for stability and operations at higher pulse levels. Standard impedance is 50 ohms, other values upon request. These units have excellent temperature characteristics and are vibration and shock resistant. Standard connectors are type "N", attenuator pads are also available with type "C".

The attenuators may be obtained as individual pads (AT-50, AT-60), or as multi-position step attenuators AT-103 (six positions) and AT-104 (twelve positions). For even greater flexibility, Attenuator Panels, Model AT-106 (two or three step attenuators in series connected) are recommended.

AT-103: 6 POSITION STEP ATTENUATOR
USING AT-50 ELEMENTS.
DC TO 4000 MC.



ATTENUATOR PADS.
DC TO 4000 MC.
AT-50: 1 W AVERAGE, 1 KW PEAK.
AT-60: 2 W AVERAGE, 2 KW PEAK.



AT-106: ATTENUATOR PANEL.
TYPICAL COMBINATION: AT-106H,
0-120 DB IN 1 DB STEPS.

*For complete technical information about attenuators for your laboratory or production needs, write for free catalog.*

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*(Continued from page 180A)*

channel unit; TME-2SD, a dual-channel unit.

Each model consists essentially of an integral regulated power supply, a transistor amplifier, and a resistance bridge and associated zero and gain controls. Except for transducers, the unit is self-contained. No additional power source or controls are needed.

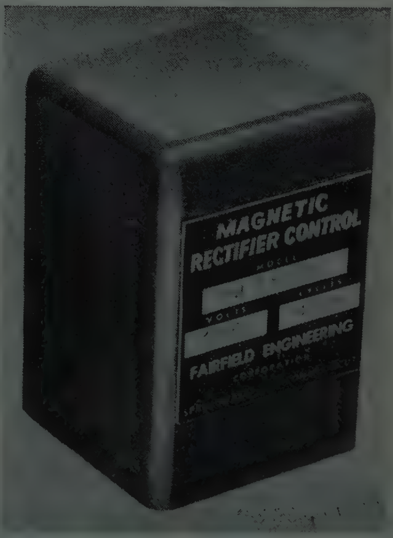
The units are designed to meet Specification MIL-E-5272A environmental conditions.

A single connector is for input, output, and power. The simple bridge controls are on top.

Nominal, over-all accuracy is ±2.5 per cent of full scale. Power consumption of TME-1SD is 26 watts and of TME-2SD is 27 watts, both at 28 vdc. Output impedance is approximately 10,000 ohms. The bridge can be balanced for a zero setting at any temperature from −320 to +250° F. Gain adjustment allows full-scale span to be varied. Maximum drift over the environmental temperature range is ±2 per cent of full scale.

## Magnetic Rectifier Controls

Driving G.E.'s new silicon controlled rectifiers, type ZJ-39A, in power control systems and servo drives is greatly simplified by the use of a new Magnetic Rectifier Control (MRC) produced by **Fairfield Engineering Corp.**, 934 Hope St., Springdale, Conn. Similar in principle to the MTC (Magnetic Thyratron Control) units manufactured by the same company, the new magnetic rectifier controls operate from low-level ac or dc control signals to develop a steep wavefront (current) to trigger the rectifiers.



The MRC units are available in a variety of models ranging from a single-phase, half-wave unit (to control a single rectifier) to a three-phase, full-wave, push-pull unit (control twelve rectifiers in a three-phase power servo system). Because the controlled rectifiers have much faster recovery time than thyratrons, 400 cps and higher frequency systems are possible, and the new MRC units have been made in both 60 and 400 cps models.

The MRC units contain specially designed magnetic amplifiers which develop a time-controlled steep wavefront of current to trigger the controlled rectifiers. By intersecting the critical firing threshold with a steep wavefront, extreme precision and control stability is achieved, practically independent of wide variations in characteristics of the controlled rectifiers.

## Temperature Monitor

A temperature monitoring system, which eliminates electronic or electrochemical scanning and substitutes continuous monitoring of large groups of temperatures by independent circuits, has been developed by the **Instrument Division of Thomas A. Edison Industries,** West Orange, N. J.

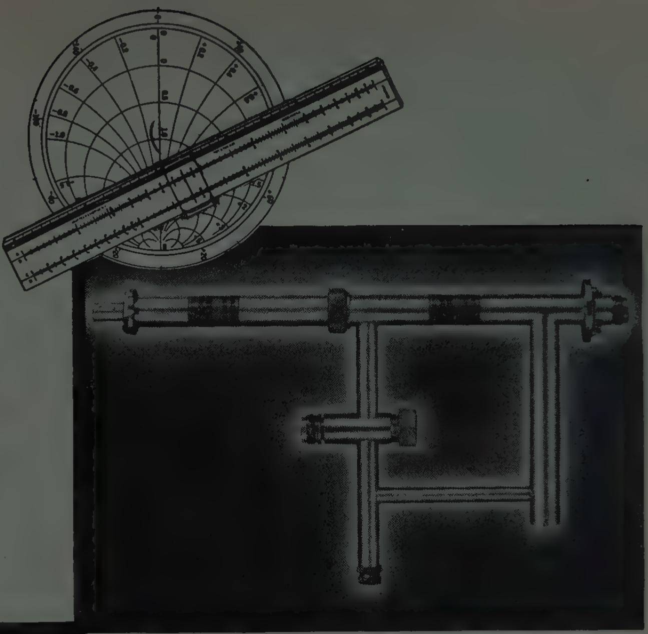
The system is basically a group of Wheatstone bridge circuits in which Edison Resistance Temperature Detectors form one leg of each bridge. An Edison current-sensitive relay across each bridge operates when the bridge becomes unbalanced due to a high or a low detector resistance. An auxiliary relay operated by the sensitive relay locks, operates an alarm light on the face of the panel and energizes external alarm devices connected to the monitor unit.

The use of independent continuously monitored circuits and only the most reliable electrical relays and components virtually eliminates the possibility of entire system failure at any particular time. Continuous monitoring also insures fast response and immediate activation of the alarm circuit.

Four bridge circuits are combined in each Model 310 Omniguard Monitor unit to monitor four temperatures. By using the "building block" principle, any number of plug-in monitor units can be grouped together with a single indicator to meet the requirements for either a small or a large installation. Momentary switches on the face of the monitor permit reading any temperature at any time.

In the past, the principal disadvantages

(Continued on page 184A)



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Select one of 8 models in the CM-107 Series, covering the entire frequency range from 225 to 5600 mc. Input VSWR of any crystal mixer in the line is better than 2:1, without adjustments, for all frequencies within its rated range. Local oscillator input requires 10 milliwatts, has a VSWR of 2:1 or better with any injector adjustment. A choice of input connectors is available. Standard models can be modified for special purposes!

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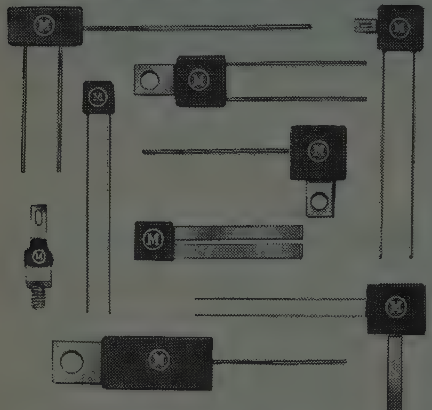

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## NEWS New Products

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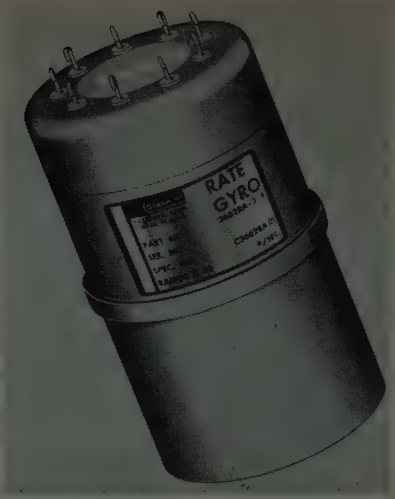
*(Continued from page 183A)*

of resistance temperature detectors were their rather large size and low basic resistance. However, this development of miniature detectors having a high basic resistance has virtually eliminated these factors. Detectors less than $\frac{1}{2}$ inch in diameter by $\frac{3}{8}$ inch long are available with a basic resistance of 120 ohms at 0° centigrade. A complete line of resistance temperature detectors is available with this system for virtually any application in the temperature range of −150° F to 1350° F.

### AC Pick-Off Rate Gyro

The Model 36628 Rate Gyro produced by **G. M. Giannini & Co., Inc.,** 918 E. Green St., Pasadena 15, Calif., utilizes an ac inductive pick-off to produce high output with excellent linearity, low null, and outstanding null stability. Oil filled and hermetically sealed, this heated unit is designed for missile and aircraft control system applications.

Ruggedness and insensitivity to mounting and dynamic loads has been achieved with the gyro's basic design. This viscous damped Model 36628 is available in rate ranges from ±10° to ±300° per second.



Because the deflection of the spring-restrained gimbal is a nominal 1.10 at full range, cross-talk and hysteresis error are minimized. The Model 36628 is designed for airborne control and telemetering applications. This instrument is suited for use in airborne autopilots for pitch, yaw or roll-rate limit signals, or for signals to pitch, yaw or roll damper systems.

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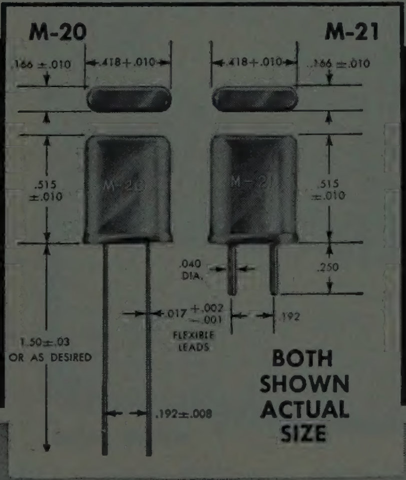

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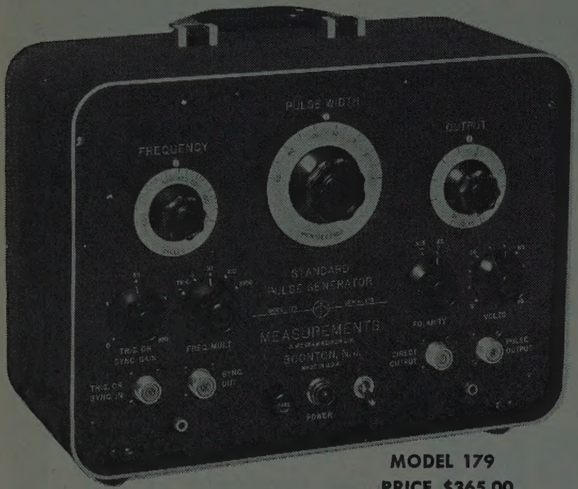

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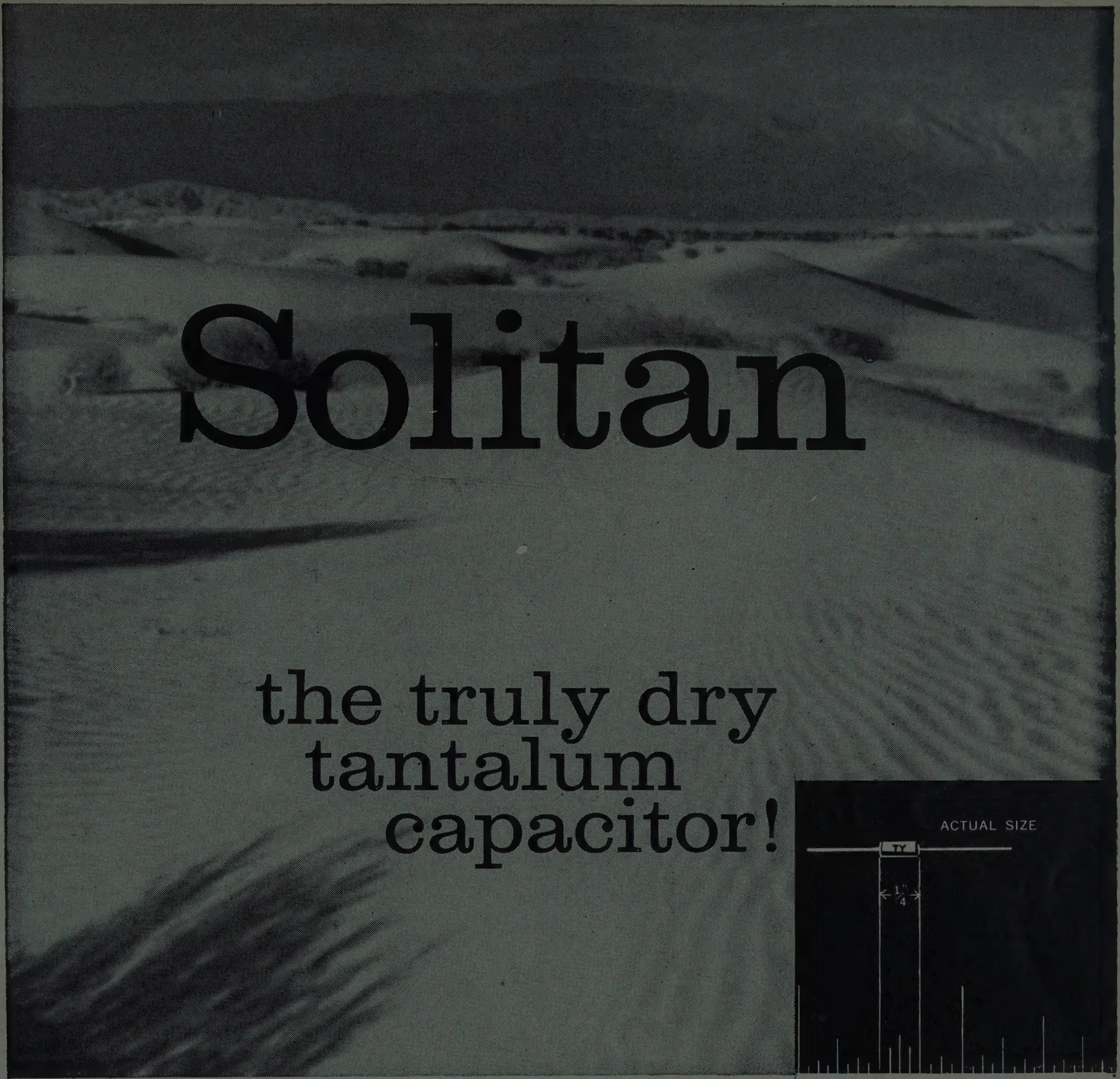

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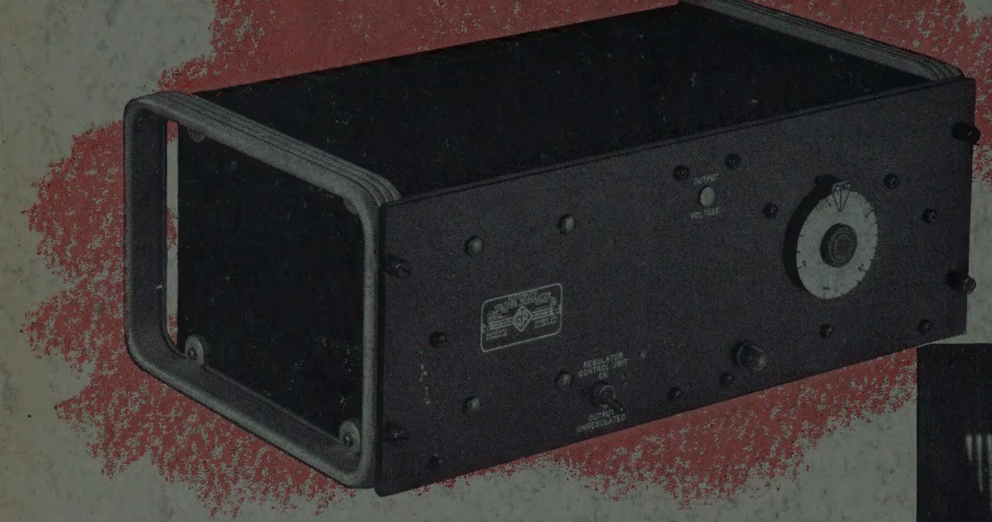

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- 50-cycle models also available

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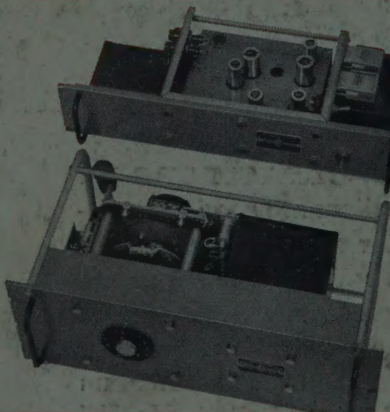

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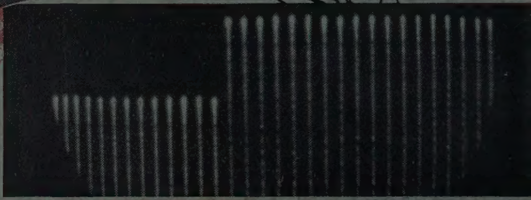

**The HUNTED** . . . any change from constan
output voltage, such as the 2% change in 60-cycl
voltage shown above. The Automatic Voltage Regula
tor will maintain output constant within ±0.25% fo
input variations up to ±10%, with 6 KVA power ca
pacity. The same model can also be easily connecte
to handle ±20% input variations at loads to 3 KV
(accuracy ±0.5%). Short period overload rating is u
to ten times steady-state rating.

A special model, the Type 1570-ALS10, is availabl
to correct ±5% voltage variations and is capable o
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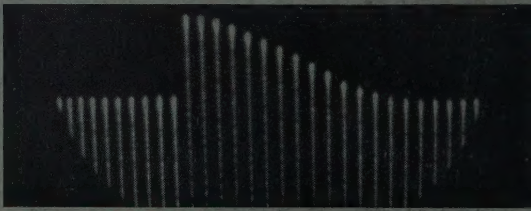
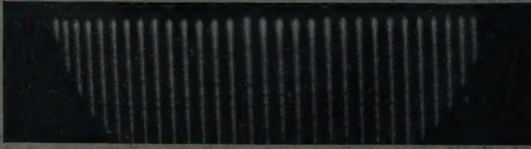


**The CHASE** . . . begins immediately with
sensing of the line-voltage variation. An error voltage
proportional to the variation, is fed to the Regulator'
two-stage balanced amplifier, then applied in push-pu
to a thyratron circuit controlling a two-phase moto
that drives the Variac. Correction takes place at th
rate of 10 volts/second (in oscillogram above, 2
change is corrected in 12c or 0.2 sec).

This instrument is a true proportional control sys
tem, rather than an off-on device. Hence, correctio
is smooth — "dead zones" are absent. Overshoot i
negligible.



**and the KILL** . . . is accomplished quickl
and neatly. No waveform distortion is introduced b
the regulator, nor are there any power-factor restric
tions. There are no relays to cause transient pulses o
chattering.

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